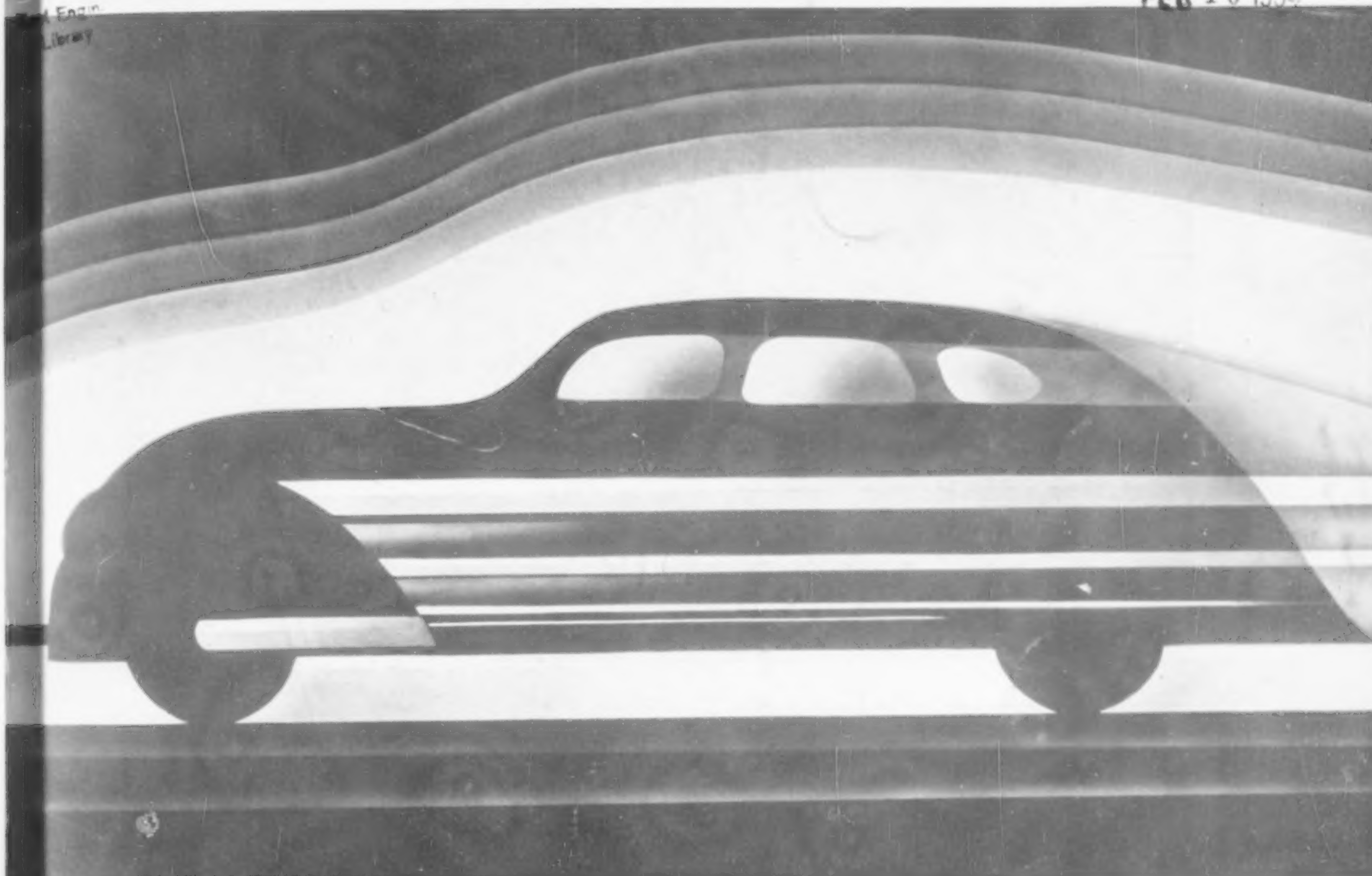
METAL PROGRESS



FEBRUARY 1934

METAL PROGRESS

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. . . . . David Zuege, chief metallurgist of Sivyer Steel Casting Co., Milwaukee, writes the article starting on page 22 of this issue which discusses the very important subject of "How to Specify Steel Castings in a Way That Will Get You What You Really Need Without Causing Unnecessary Trouble and Expense in the Foundry" . . . . He, himself, is a Wisconsin product, receiving a batchelor's degree in chemical engineering and later the degree of master of science in metallurgical engineering from the state university at Madison, and then started as an apprentice with Sivyer . . . . He is a member of the American Foundrymen's Association, the American Society for Testing Materials, and for eight years the American Society for Steel Treating (now American Society for Metals).

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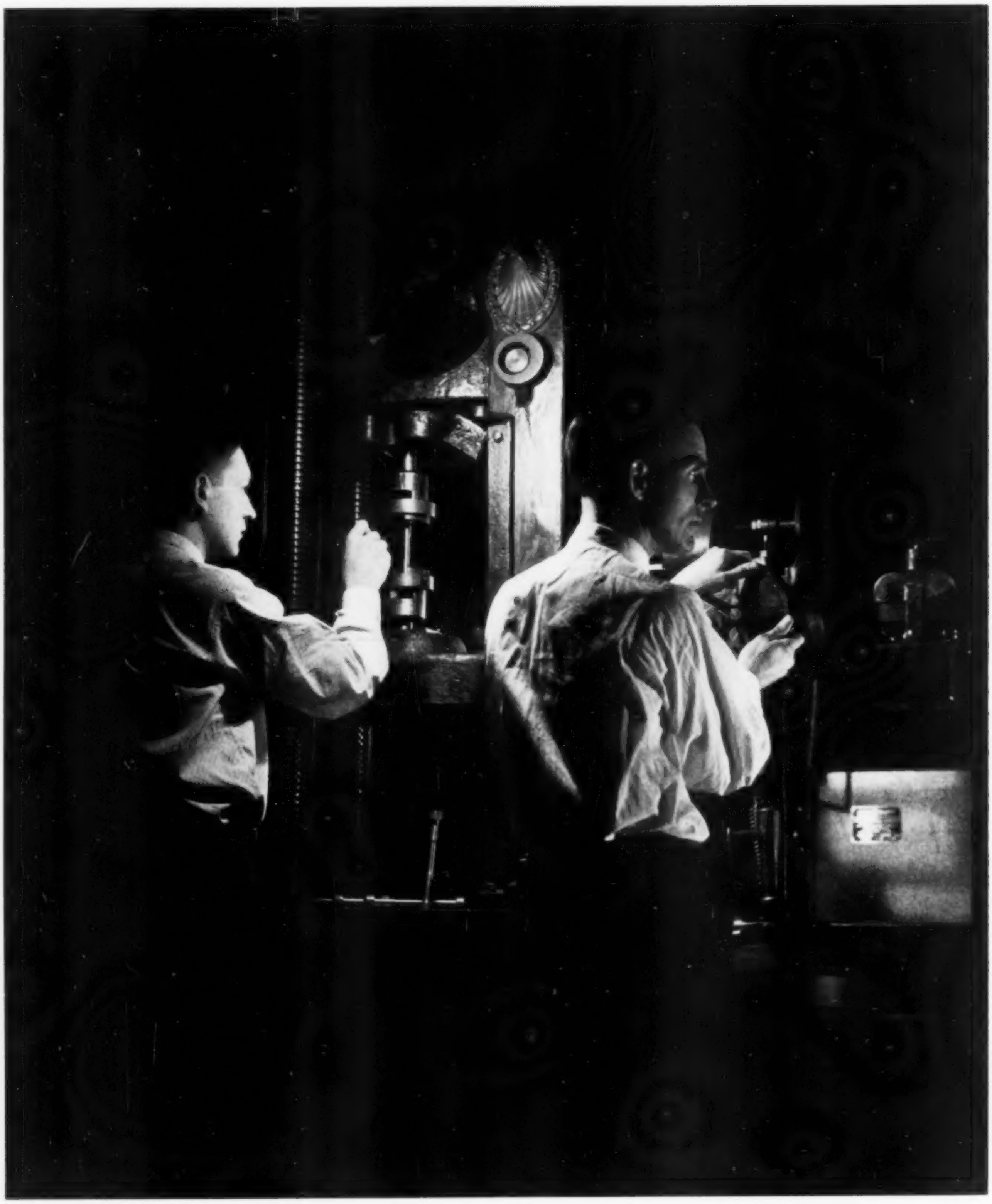
Ernest E. Thum, Editor.



Eternal Vigilance Is the Price of Safety

Photo by Tetzlaff for
Sivyer Steel Casting Co.

BETTER AUTOMOBILES

mean better metallurgy

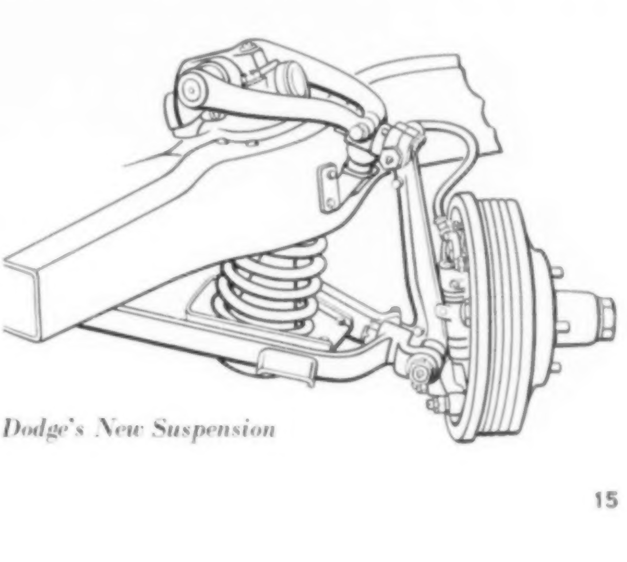
by Ernest E. Thum
Editor, Metal Progress

MOST OF THE METALLURGICAL changes in the 1934 automobiles are in line with trends dating back several years, and are being handled as a matter of routine, but the radical changes in design of the front wheel suspensions on many models have involved shop problems of far greater magnitude. Any review of the present situation should therefore start from there.

As time goes on, the American public generally will become more than adequately informed about the reputed merits of the new designs, so they need not be described in detail. They fall broadly into three systems which may be termed "wishbone," Dubonnet, and Baker; only the first two use helical springs instead of conventional semi-elliptics. The curious fact that so many cars are changing over simultaneously may be ascribed to the "follow the leader" instinct — a desire not to be caught napping in the prospective good market. Several years' experience in Europe (where independent wheel suspension is common), checked by ample road and test track driving, indicates that the new designs will be quite reliable.

Why, then, the delay in getting into production that we hear about? The first reason appears to be that the 1933 models were in good demand during the fall and were kept in production up to the last moment, and it takes a certain time to change over to any new line-up.

The second reason is that the automobile plants got into the spring manufacturing business themselves. Spring making has been in the hands of outside specialists catering to the industry, yet the makers of elliptical leaf springs and coiled valve springs were reluctant to install the necessary new machinery and special furnaces without orders or guarantees which would warrant the investment. Experience with high quality springs has generally been limited to small sizes, say a valve spring at largest, and it is quite a jump up to these new ones, which may be coils of ¾-in. rod, 5 in. outside diameter and 18 in. free height. On the other hand existing makers of heavy coiled springs have long been used to the demands of railroad rolling stock and were unwilling to meet the specifications set early in this development.



Dodge's New Suspension

This situation created the necessity of developing an art in new hands, and has provided a welcome opportunity for the metallurgists concerned to apply fundamental principles, instead of improving a conventional or inherited design. Quantity production of a heavy coiled spring really should involve (and has involved) no extraordinary difficulties. Its geometry is well known — also the mechanics of design, both under static and dynamic loads. It is made of a heat treated steel rod, and the principles of heat treatment are now better understood than ever before, and steels suitable for heavy springs in the railroad and power industry have been known for many years. Operating characteristics and dangers of coiled springs have also been long and intently studied in valve mechanisms.

Preliminary announcements from makers of motor cars foreshadow many interesting changes in design, so the editor scouted the situation as far as metals are concerned and here presents his reconnaissance

The problem was approached with the more confidence because the leading manufacturers of such parts have freely given advice from their accumulated experience in a most broad-minded manner, and preliminary experiments on springs manufactured without special precautions indicated no difficulty in approaching a life (as measured by impacts which compressed the spring to operating limits) double that of the conventional leaf springs they are intended to replace. Furthermore, conservative designers are making them slightly oversize for an added factor of safety, thus keeping the ultimate fiber stress at maximum compression down to 85,000 lb. per sq.in. in material whose yield point is approximately 170,000, ultimate tensile strength about 200,000 lb. per sq.in., and hardness between limits of 387 to 444 Brinell.

In general, the manufacture is according to the following steps: Round rod of the proper analysis is rolled to very close tolerance as to size and roundness; it is cut to length and each piece passed through a centerless grinder to remove scale, decarburized surface, and skin defects. Next the bar may be planished to iron out grinder scratches. After tapering the ends, the bar is heated to a minimum working temperature, about 1750° F., coiled and transferred hot from the mandrel to a through furnace where the heat is equalized and gradually brought to the proper quenching temperature. Quenching is done in an oil spray in a fixture under compression. Then the hardened spring passes through a drawing furnace, from which it may or may not be quenched. Lastly the coil-ends are ground for flat bearing.

The above-mentioned heating is done under such atmospheric conditions that the expensively prepared surface will be scaled as little as possible and decarburized not at all. What oxide does form is then removed with a wire brush, and the springs inspected, visually for surface condition (an all-important factor) and for hardness (that is, strength). If the springs are not housed (as in the wishbone type of suspension) they are then primed and japanned. One claim for the Dubonnet type is that they are submerged in an oil-tight case, and thus are protected from grit and corrosion, which may scratch or pit the surface at critical elements.

The above routine is varied somewhat, plant to plant. Also, as experience accumulates, design, heat treatment, and manufacturing routine will be refined to get the optimum results. Alloys may also be changed. Just now the Chrysler plants are using carbon-molybdenum steel, whereas the General Motors preference is for silico-manganese, as goes into leaf springs.

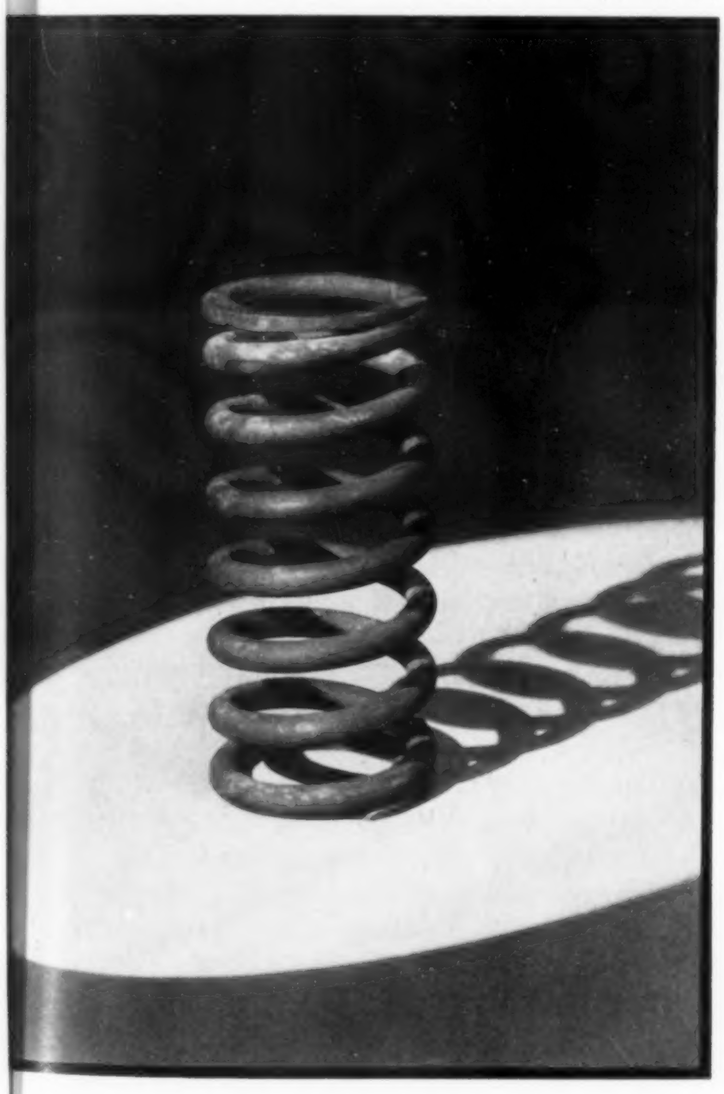
Before passing on, the real advantage of independent front suspensions may be noted. The gross weight at the front end is slightly increased, although the unsprung weight is usually reduced. A better geometry is provided for the steering system — and therefore easier driving — and the wheels may now move one-third further up or down before being checked by limit stops, and the vibration periodicity is lower by as much as 35 or 40%. Neither of the latter two advantages can be provided by redesigning the semi-elliptical springs without a

loss of sidewise stability or safety against the loads of rapid acceleration or braking, unless there is, simultaneously, a radical change in the design of the body and engine placement, as in the ultra stream-lined models. A slow period of oscillation on the main springs brings it close to the rhythm of walking rather than running, and thus is much less tiring to the occupant of the car. The ride seems smoother to him, although the maximum vertical displacement of the car due to a given bump in the road may be the same in both new and old designs.

Gears, Carburized or Oil Quenched

Agreement as to the relative advantages of carburized and oil quenched gears is a matter for the future, if ever. It does seem, however, that in those plants where ring gears and drive pinions are carburized, the work is almost always made of an alloy steel like S.A.E. 4615 which can be single quenched direct from the pot. Another advance in the study of gears is the recognition that the results of a dynamometer test or service life may depend on numerous obscure factors. For instance, changing the *diameter* of a cutter has been known to change tooth profile enough for a 20% difference in life during test. Again — at the Ford plant, special troughs have been built into a normalizing furnace reserved for ring gear blanks, and they are nested together, stood on edge, and pushed through like an unending stack of dinner plates, because any method of loading trays will produce inadmissible differences between those blanks in the top, bottom, and center of the piles.

Automobile Makers are Borrowing an Old Spring-Making Art in Their Manufacture of Large Helical Springs for Front End Suspensions. (Photo courtesy Vanadium Corporation of America)



Further notes on Ford production of oil quenched ring gears may be taken to indicate standards achieved. ("Ring" gears for the V-8, by the way, have solid centers and an axial boss at the rear, and are made of 1% chromium steel containing 0.35 carbon.) After forging, normalizing at 1850° F., and machining, the gears are heated in cyanide to 1500° F. This takes about 15 min.; the salt bath is rich in cyanide to avoid any decarburization. Quench is in oil; the press has a duplex upper clamp—the center strikes first and is held down by a heavy spring; the outer portion is under air pressure.

Quenched gears, now file hard and scale free, are washed and sent by endless conveyor through a drawing oven. Its developed length is approximately 360 ft., and the work is in it 1 hr. 35 min. A bank of electric resistors covers the floor of all the passages, and heats the air to 460° F.; for some reason this time and temperature are required to get the same effect as an oil draw at 400°, but the advantage is absolute cleanliness and no operating labor. Inspection limits for flatness are ± 0.002 in. measured simultaneously at quadrant points at the edge.

Advantages of thin-walled carburizing boxes are generally recognized. Construction of a very satisfactory type is a thin casting for a bottom to which is welded ⅛-in. sheet or cast sides, more or less corrugated for stiffness. A thin cover casting completes the job. Well-made analyses of the 35% Ni, 15% Cr type have been found to be almost everlasting (as far as scale resistance is concerned), if sodium compounds

Pinion, Ring Gear and Differential Assembly. This and the picture of cam shafts on page 21 are by Anton Bruehl for Cadillac Motor Car Co., and reproduced by their courtesy

which attack high chromium alloys are excluded from the carburizer. Boxes of this type fail by warpage — the top opening gradually changes from a rectangular to an hour-glass shape — and the material gradually absorbs carbon to become so brittle that the sheets cannot be straightened out. One help is to weld a fairly stiff beading around the top edge.

Chrysler men have pioneered the process of continuous gas carburizing of steering gears, as described fully in Metal Progress. Results have been so successful that sentiment in the Detroit district is freely expressed that this branch of the broad field of heat treatment in controlled atmosphere will be the next important change in plant practice. Change over has been slow, so far, because an ample supply of quite usable equipment is on hand for carburizing in solid compound, and it is very difficult to get an appropriation for new furnaces unless some radically new part is to be built. Another factor is that a considerable volume of production is required, so that a gas furnace can operate *continuously*.

While machinability is something that doesn't apply exclusively to gears and means different things in different shops, this absorbing topic may be mentioned in this section of the review, since it is probably the one metallurgical factor that is given most attention in the automotive industry. As pointed out by Mr. McQuaid in Metal Progress last month, a definite relationship has been established betweeen grain size as shown by the carburizing test and grain growth during normalizing, and the "machinability" of the steel. Since *uniformity* in the steel is the first consideration, uniformity of grain size and grain growth is insisted upon, and this puts a real problem into the lap of the steel maker. He, in turn, seems to have had good success with the fine-grained steels (grain size 7 and 8) and with the coarse-grained steels (grain size 1 and 2), but the intermediate ones are frequently afflicted with "duplex" microstructure — that is, substantially all grains of size 3 or 4, but with areas of 6 or 7 in a single field.

Cast Crank and Cam Shafts

Possible economies from the use of cast camshafts and crankshafts instead of heat treated forgings have been intently studied for three or four years. At present three cars in the Chrysler line as well as Hudson and Essex have cast cams, and about 1700 cast cranks for Ford V-8's are being made daily.

Many engineers are strong in defense of forged rather than cast camshafts. A camshaft is a quite simple forging, light in weight, easily heat treated to good machinability, and then readily case hardened for proper wear. In service it is 100% trouble free. "Why not let good enough alone?"

On the other hand, a modern crankshaft is a very difficult forging to make, with sharp bends close to one another and with large gatherings of metal in cheeks and counterweights. It is so heavy that muscular fatigue of the hammer man sets a definite limit on production. It has become heavier and heavier as the designers have realized that stiffness is essential, and added metal for stiffness has reduced the maximum working stresses to a figure that can easily be met in a heat treated alloy casting.

The Ford cast crank is 10 lb. lighter than the forging it replaces (70 lb.), since bearing centers can be cored out, and some surplus metal undercut from the cheeks. It is made of a patented analysis high in copper and silicon, with some chromium and about 1.25% carbon. The copper is in complete solution, thus strengthening and toughening the ferrite, whereas some of the carbon is in finely divided graphite, and this is said to improve the frictional properties.

While this casting cannot be annealed so it will cut as easily as a normalized forging, the added cost in the machine shop is not nearly as great as the saving in raw material.

After machining, the cast crank is put through the bottom hearth of a continuous electric furnace, withdrawn at 1650° F., placed on a ferris wheel where it is cooled in an air blast to 1000° F., then recharged in the upper hearth of the same furnace from which it emerges at 1400° F. for air cooling. It is now at Brinell 286 to 321 and still machinable. (This may be compared with figures for the forged crank of medium manganese steel: 402 to 444 on the body, 302 on the front end, and 208 to 228 at coupling end.)

Complete labor-saving equipment has been installed at these furnaces, so the hot crank is handled by pullers, pushers, or elevators operating in synchronism, except for skidding into and out of the quenching machine. The result is that one man can handle 5000 lb. of them per hr.

Numbers of fatigue and torsion tests have been made on complete cranks, comparing the cast and forged designs. Fatigue life of the casting in engines having the center bearing purposely out of line is about double the life of the forged crank. The modulus of elasticity is nearly the same, as is also the elastic limit in torsion — 75,000 to 80,000 in-lb. is required to cause the first deflection from a straight line on the stress-strain curve. The cast crank has little ductility in the sense that it breaks shortly after the first permanent set, whereas the steel crank will twist a complete turn before letting go. The principal practical application of the last fact is that cast cranks and camshafts must be quenched without warping, else there will be large mortality in the straightening presses.

Brake Drums

Long study of the wear resistance of various alloys and fabrics has led to the general conclusion that a laminated pearlitic structure is best to resist abrasion and scoring, and therefore should make first class brake drums. Conversely, a spheroidized structure, or one carrying free carbides, is usually not so good. Possibly laminated pearlite is preferable because such a structure resists spheroidizing quite well during those periods when the brakes are slammed on and the drum surface heats up to, say, 1300° F.

At any rate, some makers are following Lincoln's lead in making brake drums of hot pressed or rolled steel sheet of approximately eutectoid carbon (with or without alloys such as manganese). Buick is using a nickel-chromium cast iron drum, made of cylinder-block analysis, with cooling fins machined on the outside. Centrifuse drums, described frequently in recent literature, and made by centrifugal casting inside a preheated steel shell, are also widely used. Ford's rear drum is a nickel cast iron, whereas the front wheel drum and hub is an integral casting, made of short cycle malleable.

It is fair to say that remarkable progress has been made, ever since the urge for high speed has been universal, in the design of braking systems and especially in the composite brake lining materials. Brake drum troubles probably are most intense in passenger bus service, where long hills are commonly negotiated at such speed that the drums get red hot.

Successive heating and cooling cycles of this sort quickly cause internal upsetting and "alligator cracks" at the surface — a condition which cannot be cured until we learn how to abolish the coefficient of expansion, or can make drums of porous metal so there will be some internal spaces for the expansion to expand into. Be that as it may, ruinous repair bills on brake systems have been avoided by constant research which has developed linings better in every respect than the best of ten years ago.

Bearings

As a matter of fact, bearing troubles have been relatively small in automobile history — a situation which may be in a state of change, due to the severe service on high speed engines. The problem has almost as many aspects as the problem of gears, and many of them are non-metallurgical, such as proper lubrication and permanent alignment. Likewise, it is recognized that there are two surfaces to be considered, and frequently a "bearing" problem is solved by placing a smoother or a harder shaft in the same centers.

Nitrided steels have been talked about a lot, and used by our own aeronautical industry and automotive industry in Europe to reduce frictional wear, but so far Detroit is watchfully waiting. Makers of heavy duty gas engines are realizing that the journals are not as hard as they should be, and are investigating differential hardening or case hardening of these wearing surfaces. In existing engines of all kinds there seems to be a general relation between the softness of bearings and the hardness of journals. For instance, the hardest steels are frequently mated against high lead coppers, and the copper "bronzes" carrying lower lead are found installed against the softer steels. (In this connection may also be mentioned the reputed advantage of cast cranks containing a surplus of carbon which can graphitize, and thus make for a low coefficient of friction.)

Engine bearings (crank and connecting rods) are now being stressed dangerously near the limit, and much study is being given to new materials and drastic new designs. Babbitt, of various analyses, has been almost universally used since the infancy of motor cars. Trend of design is toward thinner and thinner linings of babbitt, cast inside bronze or steel sleeves for backing, all machined to close limits for interchangeability. Some difference of opinion exists as to whether a stiffer backing, as of steel, makes for better and longer service (other things being equal).

As to the metals now used, the so-called "ounce metal" (85% Cu, 5% Sn, 5% Zn and 5% Pb) is a common bronze backing, although a modification having 85% copper, 5% tin, 9% lead, and 1% zinc, or gun metal (88% Cu, 10% Sn, 2% Zn) is frequently favored. A variety of babbitts are found. Harder varieties, such as 85% tin, 7½% copper and 7½% antimony, or 84-8-8 were in earlier days used as fairly thick linings. They are now giving way to the softer babbitts (like S.A.E. No. 11 88-5½-6½, S.A.E. No. 10 91-4½-4½, "genuine" babbitt 89-3½-7½, and Britannia 90-2-8) for bearings with thin linings, even for heavy duty.

The new front suspensions require many anti-friction bearings at the linkages of the various parallelograms where roller bearings are usually installed. Designers of brake systems and lever trains attempt to get away from a multiplicity of lubricated surfaces at universal joints by installing needle bearings, which use hardened rollers, buttons, or knife edges.

Some interesting new bearing metals are now being used extensively, most notably those formed by pressing powder mixtures into precision dies in the manner described in METAL PROGRESS, July, 1932. Bushings and anti-squeak spring plates of this sort made of copper, tin, and graphite have increased by leaps and bounds in the last three years. Powdered iron, compressed and impregnated with oil, is also demonstrating its ability to carry much higher unit loads.

Interest in the "leaded bronze" bearings, adopted from railroad practice many years ago, has re-awakened from the new-found ability to increase the lead in suspension in copper even up to 45% — this material in a steel backing has given very promising results when working against journals hardened to more than Brinell 250, or even steel shafts of normal hardness. Whether their improved performance will counteract their extra cost over babbitt-lined bearings is a matter yet to be decided.

Other new materials which look very good are two cadmium-base alloys, one containing 1½% nickel and the other 44% zinc and 5% antimony. "Hardened" lead (containing about 2% of the alkali or alkaline earth metals) has also received favorable attention both here and in Germany. Recent studies bid fair to cure drossing difficulties when these alloys are remelted, which have militated against their wider use up to now.

Stainless Vs. Chromium Plate

High cost of the stainless steels and improvements in quality of chromium plate have continued to restrict the use of the former to such parts as cannot be made satisfactorily or economically in other ways. For instance, a $2 cost per car for stainless steel bumper bolts is a standing challenge for a more economical material. Trends of style have also restricted bright work on the body; generally a few lines of molding, trim around wind shield and split windows, and a radiator grille will be the limit.

Improvement in quality of chromium plate has been the natural result of intensive study by electrochemists, both in automotive laboratories and by parts manufacturers, and by the realization that a good job costs a little more than a poor one. A continued campaign of education has emphasized the importance of many essential factors, such as preliminary cleaning and buffing, sufficiently generous underplates of copper and nickel, and proper control of the chromium tank (solution, temperature, current density, and arrangement of work). Chrysler inspection measures the thickness of the coatings on a polished cross-section, as well as depending on the salt spray test.

An observer will note several somewhat novel applications of electroplating technique to other parts of 1934 automobiles. For instance, Buick valve lifter rollers and pins are copper plated to avoid scoring during the "run-in" period, and cast iron pistons are tin plated for the same reason. Aluminum pistons used by many engine builders are "reverse plated" — that is, given an oxidized surface — to improve the adhesion of oil films; exposed body parts like aluminum grilles are treated similarly for a weather-proof luster.

BETTER STEEL CASTINGS

reflected in specifications

by David Zuege
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GREAT IMPROVEMENT IN PHYSICAL and chemical properties has characterized the progress of the steel castings industry during the past decade. Extensive research has discovered a large number of new compositions capable of extraordinary serviceability for many exacting applications. During this time the activities of national organizations that formulate specifications (such as the American Society for Testing Materials) have appeared to some persons inadequate to reflect the progress that has been made. In 1930 there were four specifications for carbon steel castings, known in trade parlance as "miscellaneous" (A 27-24), "railroad" (A 87-27), "high temperature valves" (A 95-29), and "stud-link chain" (A 77-28 T), and there was only one specification for alloy steel castings — "Hadfield's austenitic manganese steel" (A 128-30 T).

Considering the vigorous efforts of some producers to exploit their special products, it is not surprising that a large number of private specifications were formulated. Although many such specifications are entirely satisfactory, some of these apparently were patterned after acceptable specifications for wrought material and show lack of knowledge regarding the differences of manufacturing procedures based on sound metallurgical principles which differentiate the production of rolled from cast steel. As for the existing A.S.T.M. specifications, there were rather wide differences in chemical and physical requirements for approximately the same grade of carbon cast steel intended for different structural services.

To correct this situation a special committee was appointed in 1930. An account of the work done by it may be found in articles by R. A. Bull in *Steel* for October 2 and 9 last. This committee wrote a specification which was adopted as a tentative standard last summer by the A.S.T.M. entitled A 154-33 T, "Carbon Steel Castings for Industrial, Railroad and Marine Uses," and is intended eventually to supersede existing specifications in those three fields. It includes more comprehensive chemical restrictions than the older specifications, and prescribes physical properties in accordance with the results of improved foundry practice.

No physical requirements are specified for Class A castings of plain carbon steel; its carbon content is specified mainly to identify the material as a grade of steel suitable in the "as cast" condition if not subjected to severe stresses.

Analysis of Carbon Steel Castings

A.S.T.M. Specification A 154-33 T

Carbon (Class A)	0.45% max.
(Class B)	not specified
Manganese	0.50 to 1.00%
Silicon	0.20 to 0.75%
Phosphorus	0.05% max.
Sulphur	0.06% max.

Carbon content in Class B is not prescribed. Castings in this class are subdivided into four grades, in each of which tensile requirements are specified. The grade most commonly used is designated as "Regular"; it is suitable for most structural purposes, much railroad work, and many parts for ships. The minimum requirements for yield point, elongation, and reduction of area are increased by about 20% above the corresponding values in A 27-24 (see the accompanying table). "Special Grade 2" and "Special Grade 3" are used mainly for large railroad castings; the carbon (while not specified) is low, for good machinability and weldability. "Special Grade 4" is intended for miscellaneous uses where higher strength is required than can ordinarily be had in the "Regular" grade, and where no more than a fair amount of ductility is required.

Chemical specifications for manganese and silicon are the same in both Class A and Class B, as shown above, and are in keeping with their importance in the production of a sound foundry product. Both are very active degasifiers, and fortunately also improve the physical properties.

It should be emphasized that the physical properties noted in the table are *minimums* and obtainable without liquid quenching or spraying. It is not intended that an upper limit should be placed on any tensile property, for high combinations may be developed by proper heat treatments.

Alloy Cast Steel

The situation with respect to physical requirements of the alloy structural cast steels has differed from that involving the carbon steels. Until 1933, as previously indicated, there was but one A.S.T.M. specification for an alloy cast steel (Hadfield's manganese steel), although in 1932 special metals constituted 19% of the total steel castings output. Naturally the commercial conditions resulted in a considerable number of private specifications. Many of these purchase requirements for physical tests reflect the buyer's accurate knowledge of the metallurgical characteristics of the material involved, but this is not always true. Typical of the class to which objection can consistently be made, some private specifications restrict the yield point and tensile strength to maximum as well as minimum limits, thereby causing an unjustifiable increase in cost. Higher values for yield point and tensile strength than those specified are advantageous rather than detrimental, providing the elongation and reduction of area are not decreased.

In June of this year, the new specification A 148-33 T, "Alloy Steel Castings for Structural Purposes" was adopted as a tentative standard, as already mentioned. Naturally it includes a number of classes and grades — a lesser number would not meet commercial conditions, since approximately 70 distinct alloy cast steel compositions are being produced today, and the

Minimum Tensile Properties for Steel Castings

	Tensile Strength	Yield Point	Elongation in 2 In.	Reduction of Area
Carbon Steels (A154-33T)				
Class A	No tensile requirements			
Class B; Regular grade	70,000	38,000	24	36
Special grade No. 2	60,000	30,000	22	30
Special grade No. 3	60,000	30,000	26	38
Special grade No. 4	80,000	43,000	17	25
Alloy Steels (A148-33T)				
Class A; Grade No. 1	75,000	40,000	24	35
Grade No. 2	85,000	53,000	22	35
Class B; Grade No. 1	85,000	55,000	22	40
Grade No. 2	90,000	60,000	22	45
Grade No. 3	100,000	65,000	18	30
Class C; Grade No. 1	90,000	65,000	20	50
Grade No. 2	120,000	100,000	14	35
Grade No. 3	150,000	125,000	10	25

physical properties of most of them may be modified through a wide range by heat treatment. For the same reason no chemical restrictions were included except a 0.05% limit for phosphorus and a 0.06% limit for sulphur.

Minimum tensile properties required are shown in the lower part of the table just above. Explanatory notes describing the three general classes may be paraphrased from the specification as follows:

Values specified for Class A may be met and exceeded by castings of such size or shape as to be unsuitable for anything more drastic than full annealing (that is, furnace cooling).

Class B represents minimum values for normalized castings (air cooling from above the critical temperature). Such air cooling is a safe procedure for the great majority of alloy steel castings intended for structural purposes, and usually develops the highest tensile strength and yield point values that can be obtained from the material by any method of heat treatment, except liquid quenching.

Class C is intended to include castings suitable in composition, design, and dimensions for rapid cooling, as by liquid quenching followed by a drawing operation above 400° F.

Notable improvements in the properties of steel castings, both plain carbon and alloy steel, adequately heat treated, have been incorporated in the recently adopted A. S. T. M. specifications. Mr. Zuege, who has been with Sivyer ever since graduation, indicates those points where leading foundrymen are able to guarantee additional physical requirements as demanded by unusual applications.

Class B includes the greater portion of the alloy cast steels regularly made in the jobbing electric steel foundry. Grade 1 of Class B is intended primarily to cover steels of the so-called intermediate manganese type, having a manganese content that may range from 1.15 to 1.60%. Grade 2 of Class B covers cast steels with higher strength and ductility. Several of them are of the intermediate manganese type, but contain a supplementary alloying element, such as nickel, vanadium, or molybdenum. Grade 3 includes compositions having relatively high strength and stiffness, such as the chrome-nickel, chrome-molybdenum, or chrome-vanadium steels.

Although quenched castings constitute only a small part of the total output, certain advantages are to be obtained by liquid quenching and tempering castings of suitable design and composition, and the amount of such heat treated castings is rapidly increasing. Hence the desirability of Class C in the specification.

As is true of the carbon steel castings, it should be remembered that the values given in this new specification for alloy steels are *minimum* or rejection limits, and are not representative of the average physical properties being obtained in progressive foundries. As an example of what is being regularly produced in one foundry, a series of 12 heats made to requirements for Class B, Grade 2 may be described. A wide variety of castings for severe duty was made on these heats, including 450-lb. single throw crankshafts.

Test coupons were attached to each; the nominal chemical analysis was 0.28 to 0.38% carbon, 1.20 to 1.50% manganese, and 0.10% vanadium, and test pieces representing normalized and drawn castings produced the results in the table given at the top of the next column. It is clear that a superior product has resulted.

As a further indication of representative physical properties, the curves opposite show values obtained upon heat treating a typical heat of the same material. The steel in question analyzed 0.37% carbon, 1.44% manganese, 0.43% silicon, and 0.13% vanadium. Bars 1⅛x1⅛x8 in. were cast, and heat treated as follows: Normalized at 1650° F., water quenched from 1525° F., and drawn by 100° steps from 600 to 1300° F. Standard ½-in. test bars were then machined out and pulled.

Requirements for all three grades of Class C castings are plotted by horizontal lines on the same diagram, and it is obvious that a low draw will easily exceed the specified minimums for Grade 3, intermediate draws will qualify as Grade 2, and high draws will give the high ductility required for Grade 1.

In choosing a specification the consumer must give due consideration to the fact that some castings, because of size and design, cannot be subjected to rapid cooling, and that therefore the requirements under Class C cannot be secured. In such instances cooperation

	Maxi-mum	Mini-mum	Aver-age	Specification Require-ments
Tensile strength	110,100	90,300	97,920	90,000
Yield point	77,750	62,800	67,750	60,000
Elongation in 2in.	28.5	22.5	25.7	22
Reduction of area	58.9	48.9	54.4	45

between producer and consumer will usually result in the proper selection of required mechanical and chemical properties.

Hardness and Impact Tests

Tension tests are still the only qualification tests required by the above-described A.S.T.M. specifications, with the exception that specimens representing marine carbon steel castings (regular grade, Class B) must bend around a 1-in. pin without cracking.

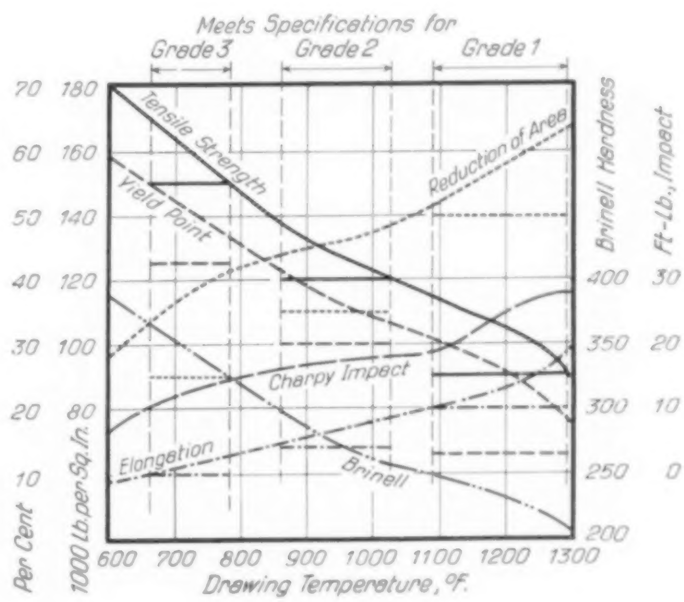
Hardness tests, not called for in the A.S.T.M. specifications for steel castings, are now commonly required, and probably will increase in popularity as the percentage of liquid quenched castings increases. All three of the commonly used hardness testing methods (Brinell, Shore scleroscope, and Rockwell) are being used for hardened steel castings, each having certain advantages. The Brinell test with its relatively large indentation has usually been found most satisfactory for cast steel surfaces, even after suitable grinding.

Unlike tension test requirements, for which minimum values only are prescribed, hardness specifications usually set (very properly) maximum and minimum values. In selecting the range, consideration must be given to the fact that it is much less difficult to maintain a Brinell range of 179 to 207 than to maintain one of 415 to 444, although the "spread" is approximately 28 points in each case. High hardness is secured after tempering in a relatively low range, where a small variation in temperature affects the hardness more pronouncedly than the same variation at higher draw temperatures. Again, 0.1 mm. difference in the diameter of the indentation means a change in hardness value of about 8 units when the hardness is about 200, but the same difference means 29 points at hardness values about 400. For these reasons at the higher hardness values a range of not less than 50 points in Brinell hardness should be allowed, while at the lower hardness values a 20-point range is usually satisfactory.

Another factor, not always given proper consideration, involves a casting having a wide variation in the thickness of its section. It is practically impossible to obtain a uniform hardness value throughout, because of the difference in cooling rates of the various sections. This is true particularly at the higher hardness values.

Although other tests such as those for impact, creep, fatigue, and wear are made in increasingly greater numbers upon alloy cast steels, such values usually are not included in specifications. The most important of these is the impact test, since it evaluates ability to withstand the suddenly applied loads often encountered in service. A high impact value generally is accompanied by excellent ductility values as determined by the tensile test, but high ductility results do not always indicate good impact resistance. The data in the table on the next page, obtained in testing a simple alloy cast steel, heat treated according to different procedures, illustrate this point.

It is unfortunate that the impact test has not been standardized. Two types of machine, the Charpy and the Izod, are in general use,



Properties of Heat of Steel with 0.37% Carbon, 1.44% Manganese, 0.43% Silicon and 0.13% Vanadium Can Be Varied Widely by Normalizing, Quenching and Appropriate Draw

each having at least two varieties of test specimen. Differences also occur in the type and dimensions of the notch used in the various specimens. Therefore, in interpreting impact data it is most essential that consideration be given to the method of making the test.

Many attempts have been made to establish a definite relationship between Izod and Charpy values. Although a direct ratio may be found

	No. 1	No. 2	No. 3
Tensile strength	84,450	82,050	82,000
Yield point	49,050	46,000	48,150
Elongation in 2 in.	29.0	30.0	30.5
Reduction of area	61.0	62.0	62.3
Charpy impact, ft-lb.	9.0	17.0	22.5

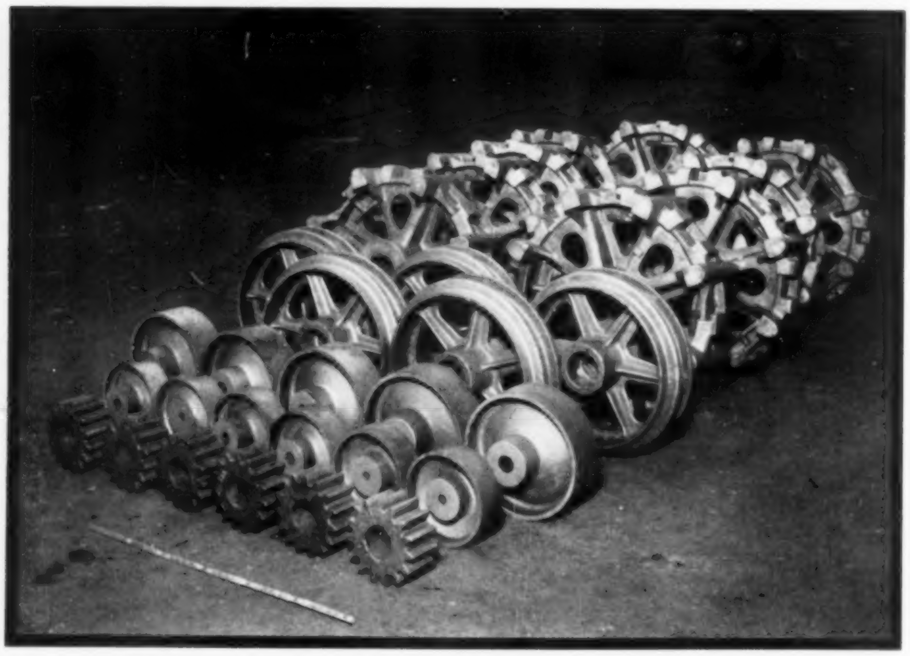
in certain grades of steel, it does not hold in others. At the lower values (about 3 ft-lb.) the results are similar, but as the toughness increases, the "spread" between them becomes greater. With one grade of simple alloy steel, 25 ft-lb. Izod is roughly equivalent to 15 to 20 ft-lb. Charpy; 50 ft-lb. Izod approximates 25 to 30 ft-lb. Charpy for the same steel, heat treated differently.

Notwithstanding this lack of standardization, the information obtained through impact tests is of sufficient value to justify requiring minimum values in certain specifications to supplement the tensile values, where consumer and producer agree on the method of testing.

Valuable Supplemental Factors

Purchase requirements adopted by the Testing Society should be used whenever possible, since they have been formulated only after the accumulation of considerable data and lengthy deliberation by consumers and producers regarding all factors involved. However, supplementary requirements are in many instances justified, and in such cases should be developed cooperatively by consumer and producer in the interest of economy. Information on both sides of each question should be sought.

A final point is worthy of consideration. The purpose of the modern specification is to obtain uniformity of good properties in a carefully selected grade of metal going into the casting. The physical properties are usually determined from test pieces cast either attached to the casting or as separate blocks made in the same heat. Other factors than the mechanical properties of the metal (many of which cannot be written into specifications, such as design, heading and gating methods, and heat treating procedure) vitally affect the serviceability of the casting. As the tonnage of special or alloy steels increases proportionately in any plant, knowledge is acquired through experience by which foundry technique is improved, resulting in a product of good metallurgical qualities, true to pattern, and free from objectionable casting defects. Improvements in molding, core making, and other shop practices have kept pace with those effected in the properties of the metal used. It is confidently predicted that the future will see an even greater achievement in all significant factors, some of which can never be specified in a written document.



These Castings Are Differentially Hardened to Meet Rigid Specifications. Lugs for test bars are attached to castings, and are cut off and tested after the required heat treatment is entirely finished

STEEL IS EMBRITTLED

if quenched in critical range

by James J. Curran
Metallurgist
Henry Souther Engineering Co.
Hartford, Conn.

METALLURGICAL LITERATURE abounds in discussions of various types of brittleness and brittle ranges in steel, and the conditions which cause or favor brittleness. Nevertheless, there is one brittle range in quenched steels which has not received adequate attention. We have not yet been able to investigate this as minutely as we would like to, or as its importance warrants. Nevertheless, we feel that sufficient evidence exists to prove that it does exist and to indicate where it may affect the properties of steel in various common commercial operations. It appears to have been hitherto unrecognized, although subsequent to our investigation, H. H. Bleakney described in *Transactions*, A.S.S.T. last October, something that may be another phase of the same phenomenon.

During the War, we had occasion to salvage a lot of case hardened 3½% nickel steel parts, which had accidentally been made of steel containing 0.35% carbon and which, as a result, failed to develop the desired toughness of core. In the investigation, the critical points were determined by heating small sections of the steel in contact with a thermocouple in a small quartz-tube electric furnace. Subsequently, short sections were heated and quenched in oil at intervals of 10° F. from temperatures in the neighborhood of the critical range, using the same furnace and thermocouple. The quenched specimens were then subjected to a simple bend test by clamping in a vise and hammering.

Specimens quenched from temperatures below Ac_1 (1290 to 1300° F.) proved extremely tough, and could be hammered through 90° and then closed up flat in the vise. At Ac_1 and very slightly above it, the quenched specimens showed pipe-stem brittleness, breaking off with a single blow of the hammer, yet specimens quenched from still higher temperatures were tougher, and would take an appreciable bend before breaking. As the quenching temperature was raised further conditions reversed, as the material became increasingly brittle (which might normally be expected for material of this composition in the quenched condition).

All of these specimens were small, about ¼ in. diameter by 4 in. long, were heated in close contact with the thermocouple, and were all quenched on a rising heat — that is, without soaking at the quenching temperature. Some of the tests were repeated, utilizing a short soaking period of about 5 min. at heat. It was observed that specimens so soaked and

quenched had the same bending ability as those which were quenched from slightly higher temperatures on a rising heat; furthermore, the brittle range in pieces soaked and quenched immediately above Ac_1 was not so noticeable.

Several steels, if quenched from just above Ac_1, lack both the ductility and hardness they possess after a higher quench. Mr. Curran (who has been a member of the Society since 1920) thinks this may be a property of all steels, and cites some operating troubles which may be due to it.

From time to time in the intervening years, cases of brittleness and unexpected variations in properties of steels when quenched (or even annealed) close to the critical range reminded us of the curious behavior of the nickel steel just described. As a result, it was decided to repeat the war-time tests on a variety of steels, and samples of six types were obtained in the form of cold drawn rounds and hexagons, varying somewhere from $\frac{1}{4}$ to $\frac{3}{8}$ in. in diameter, as follows:

Chrome-nickel; S.A.E. 3135
Nickel; S.A.E. 2330
Chrome-vanadium; S.A.E. 6150
Chrome-molybdenum; S.A.E. 4140
Manganese free-cutting; C 0.35%, Mn 1.50%, P 0.06%, S 0.15%
Carbon; S.A.E. 1035

Bars were cut into sections, 3 to 4 in. long, heated for quenching in a small electric muffle furnace, automatically controlled, and quenched in oil from various temperatures in steps of 20° F. from 1260° F. to 1520° F. For each test, six specimens, one of each type of steel, were placed on a tray in the furnace with the thermocouple close to the work. The controller was set at approximately 60° F. below the temperature from which they were to be quenched, and when specimens had reached this temperature they were allowed to soak for a few minutes to equalize the entire piece.

The controller was then reset at the desired quenching temperature. When this was reached — that is, when the controller first cut off the current — the tray was quickly withdrawn and the contents quenched in oil. The time of heating from the preheating temperature to the quenching temperature averaged about 8 min. for the various experimental heats.

After cleaning, the quenched specimens were tested by hammering in a vise, bending them until they broke or until they flattened on themselves. Rockwell hardness tests were also made on the C-scale ("minus" values being recorded and plotted to avoid changing the scale); the angle of bend and hardness are shown in the curves herewith, plotted against the quenching temperatures. The appearance of the specimens is also shown in the photograph on page 30.

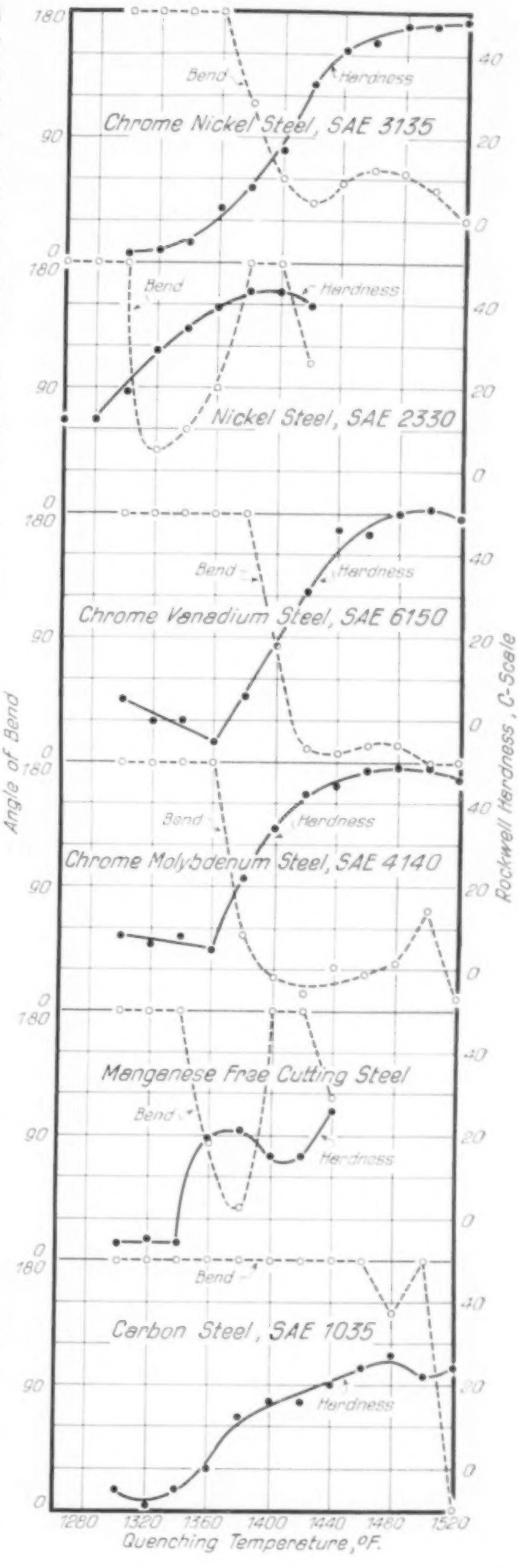
Examination of the curves will show that whereas the hardness of the various steels increases with more or less regularity with hardening temperature after Ac_1 has been passed, the ductility as measured by the bend test does not vary in a regular manner. In all except the straight carbon steel, a decided loss of ductility occurs as soon as the Ac_1 has been passed, dropping to a minimum in each case, then increasing, and then falling away again as the quenching temperature is increased. In the case of the $3\frac{1}{2}$% nickel steel S.A.E. 2330 and the high manganese free-cutting steel, this temporary recovery of high ductility is most marked, but all of the steels tested show signs of the same tendency.

Microscopic examination of the nickel and manganese steel specimens shows no unusual structural characteristics. In each instance the inception of brittleness in the specimens coincides with the first appearance of martensite. With increasing temperature, the martensite grains become progressively larger and lower in carbon content, by absorbing ferrite from the matrix. Finally, at Ac_3, a homogeneous solid solution free from ferrite results, and at the same time the steel recovers a high degree of toughness. At higher quenching temperatures, the grain size of the solid solution increases, and the brittleness once more makes its appearance.

While our tests indicate that the nickel and manganese steels are most seriously embrittled by quenching from just above Ac_1 (and show the best subsequent recovery), we are not prepared to say that the other steels tested will not exhibit this phenomenon more markedly than our rather limited tests to date might suggest. Rather, we believe that a more exhaustive examination with more delicate tests will show that all steels exhibit — to a greater or less extent — the same brittleness when quenched just above Ac_1 and subsequent relatively high recovery of toughness when the quenching temperature is suitably raised. Further, it is entirely possible that this phenomenon is not a function of chemical composition alone, but that some heats of a given analysis may exhibit it to a greater extent than others. Such differences from heat to heat are not unusual, as evidenced by variations in susceptibility to temper brittleness, and variations in "timbre," abnormality, inherent grain size, and grain growth at carburizing temperatures.

The torsion-impact test recently developed by

Samples of Stock Bars Were Quenched in Oil From Slowly Rising Heat. Ductility (bend test) and Rockwell hardness measurements indicate an anomalous behaviour just above the lower critical, consisting of a minimum ability to withstand a bending test



Luerssen and Greene and described before the Detroit convention should prove valuable for measuring variations of brittleness — or toughness — with quenching temperature, and throw more light on the actual susceptibility of various compositions and different heats of the same composition.

To date, our tests indicate that critical range brittleness does not persist to a noticeable extent in quenched steels after relatively high draws, as for instance, 60 min. at 1000° F. Hence its importance is probably limited to the quenched or rapidly cooled conditions.

This entire matter is of more than academic interest. In the past, the tendency has been to specify low quenching temperatures, and to quench on a rising heat (or at least with a minimum of soaking) to minimize grain growth, brittleness, and other hardening difficulties. Our tests indicate that such procedure is not always desirable; in fact, it may be dangerous.

The work of Publow and Fitz-Randolph on the microstructure of hardened carbon steel (Michigan

Engineering Experiment Station Bulletin 45) demonstrates clearly that the critical point of a slightly hypereutectoid steel is in reality a definitely measurable temperature *range*, and that a considerable change in microstructure and properties is discernible in specimens quenched throughout this range. Hence, we are inclined to believe that the brittle range which we have demonstrated in medium carbon alloy steels may also be present and demonstrable in high carbon steels.

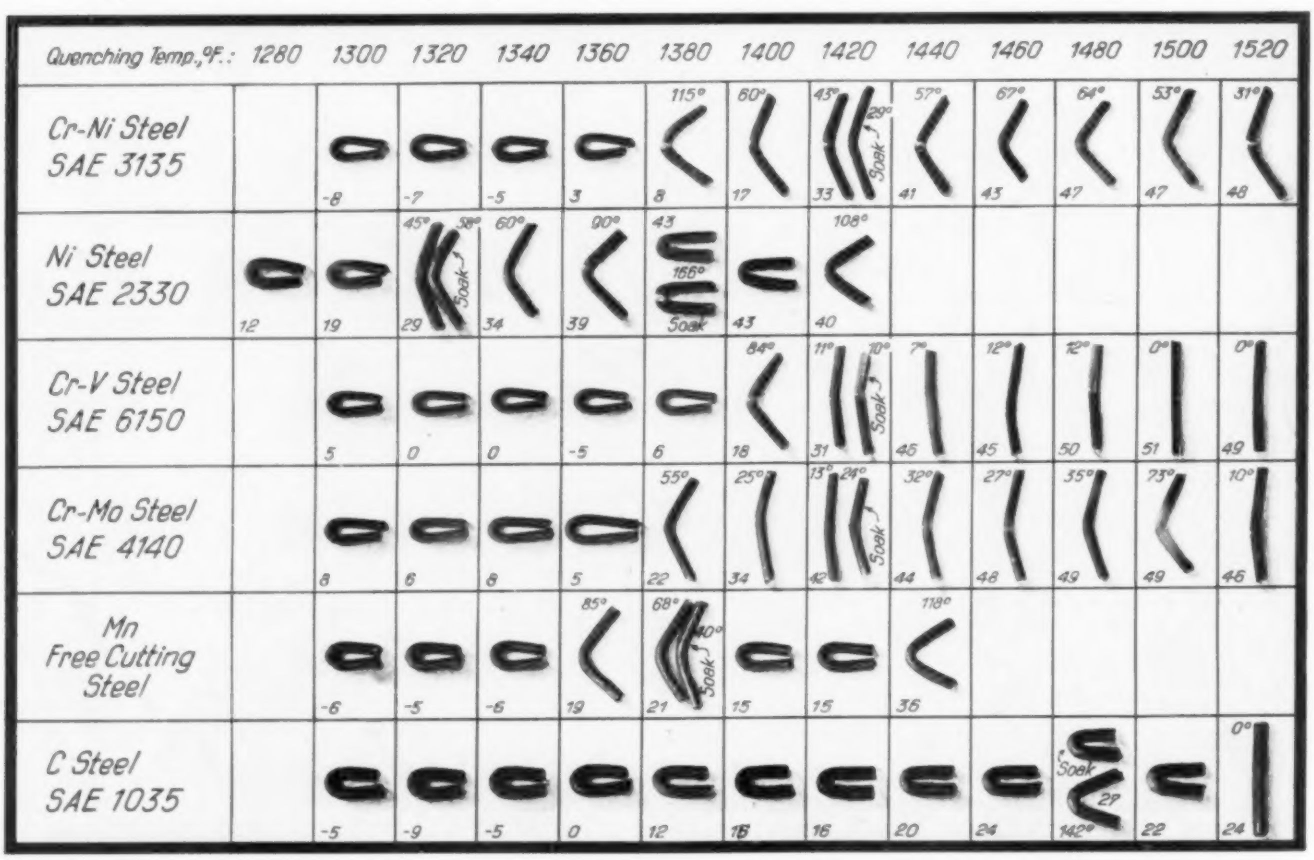
Such steels often show brittleness which is not yet entirely explained. For instance, we are all familiar with the checking or shelling off of edges and corners of tools, usually when quenched from a low temperature or on a rising heat. Also, a sharp quenching line usually results in abnormal brittleness in a tool which is hardened locally. In each of these instances, a temperature gradient exists prior to quenching, and some portion or zone will be quenched from just above Ac_1 — that is to say, in the range where brittleness may be produced.

In carburized parts, where the final quench is kept low to harden the case and toughen the core, there is danger that increased brittleness of the core may result. Knowledge of the location of the brittle range and the recovery range for both the high carbon case and the low carbon core will permit one to select a quenching temperature that will insure the best combination of surface hardness and core toughness. It is possible also that the brittleness here described is a factor in exfoliation — cracking or shelling of the case in or after hardening.

A steep temperature gradient also always exists between the actual weld and the part being welded. Where the part is of large mass and not preheated, the heated portion cools very rapidly — equivalent to a quench. It is reasonable to suppose that that zone which was heated only just above Ac_1 point will be embrittled by this rapid cooling. This would explain, in part at least, why unannealed welds usually fail in the adjoining metal and not in the weld itself.

It is believed that a thorough investigation of the brittle range described would result in valuable additions to our knowledge of the metallurgy of steel, and the proper heat treatment and application of the varied compositions now in use. Additional information on it would be very welcome.

Appearance of Quenched Samples After Testing — Degree of Bend and Rockwell C-Scale Hardness Is Noted



EDITORIAL COMMENTS

on items of interest today

Economics in Technical Courses

TECHNICAL education is a matter close to the heart of the American Society for Metals, for the Society is essentially an institution for "adult education" (as the pedagogues would call it) the spreading of information before men who can absorb and use it. Hence an interest in the perennial projects to improve the course of studies in engineering colleges by adding this, that, or the other subject.

A recent one was the plausible proposal to teach economics to engineers. It was argued that few engineers occupy the highest positions, directing large corporations, not because their technical ability is lacking, but because they are unable to grasp the intricate relationships of employment, management, buying, and selling. So, teach them economics!

To the editor, the reason why engineers are engineers rather than business men is far more fundamental than a single college course — it results from a queer quirk in their mentality. If they were interested in management or politics, they would not study the technical sciences; they would frankly leave that to others and become business men or politicians in the first place, and if they tried engineering, they would most likely fail. And, by the same token, engineers are engineers because they would rather deal with the somewhat predictable action of inanimate things than to gamble on the psychology of the human race.

Have Engineers Any Place in the New Deal?

APPARENTLY the New Deal means as many things as there are persons, and to some in the mechanical industries it has created a wonder as to whether there will be any place for them in the economy of tomorrow. It is obvious that we have improved our processes and expanded our capacity to where existing plants can produce far more than our own people have been able to consume (buy). Does the adjustment between supply and demand require a long period when technical improvements will be avoided, labor-saving devices prohibited, and new equipment unsalable? Can an outlet for "capital goods" be found here or abroad?

The President's message on the opening of Congress, which emphasized his view that reform of the abuses which have brought us to this pass is even more necessary than temporary means for recovery, contains these words as to his continuing program:

"The program . . . . is an integrated program, national in scope. It is designed to save from destruction and to keep for the future the genuinely important values created by modern society. . . . . We would save useful mechanical invention, machine production, industrial efficiency, modern means of communication, broad education. . . . . But the unnecessary expansion of industrial plants, the waste of natural resources . . . . we must make sure that as we

reconstruct our life there be no soil in which such weeds can grow again."

Here is a reassuring statement of a political creed which squares itself with sober philosophy, economics, and history. It says in effect — give us the labor-saving devices and reduce the average working day correspondingly; give us the improved tools and equipment, the new inventions, the scientific discoveries, the industrial efficiency, and spread the resulting advantages broadcast so that *all* our citizens can enjoy a fuller and a better life.

Induction Furnaces Vs. Open Hearth

THAT the biggest is not always best — despite the current estimate of American publicity agents — is once more proven by the rapid adoption of high frequency induction furnaces. Here is a flexible, speedy, and efficient unit that has given first aid to many a manufacturer of alloy steel ingots and castings. Despite the fact that its first cost (together with electrical auxiliaries) is perhaps four times as much as arc furnaces of equivalent capacity per day, the collateral advantages enable the small high frequency furnace to operate while the larger arc furnace is cold.

The advantages in dollars and cents would be more real if a melting department using high frequency furnaces exclusively were to be installed from the ground up. As compared with an open-hearth furnace plant, the buildings would be much smaller and lighter, the cranes of only a fraction of the power and cost, the ingot mold capacity much reduced, and the soaking pits more economical. D. F. Campbell has figured that the capital invested in a steel works making 1000 tons a day would actually be less for induction furnace melting than for open hearths. While his figures may perhaps be shaded by enthusiasm, there is undoubtedly some such figure which separates the economic field of the old and the new processes, even when working on common carbon or low alloy steels. Furthermore, this dividing figure will be the larger as the more stress is laid on uniformity of analysis and quality of product.

Ac_3 Figured From Analysis

A FORMULA for figuring the upper critical temperature (Ac_3) of S.A.E. steels was divulged to a joint meeting of the Society of Automotive Engineers and the American Society for Steel Treating (or should we say American Society for Metals?) by Robert R. Abbott of White Motor Co. It is the result of work done prior to the War on about 400 bars of fine steels gathered from manufacturers here and abroad. Each of these steels was annealed, analyzed and its critical point determined by quenching from a lead bath by 1° C. steps and finding the temperature where the last traces of ferrite were absorbed.

By a series of approximations and corrected formulas figured laboriously by the method of least squares, the following formula results:

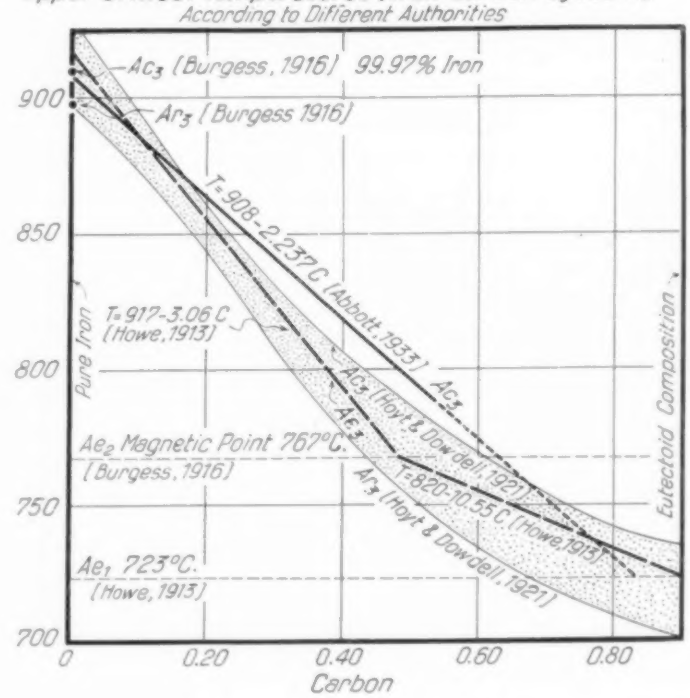
Take Ac_3 for pure iron as 908° C.

Add 0.4385° C. for each 0.001% phosphorus
0.3049° C. for each 0.01% silicon
0.3792° C. for each 0.01% vanadium

Deduct 2.237° C. for each 0.01% carbon
0.3443° C. for each 0.01% manganese
0.23° C. for each 0.01% nickel

Besides the above deduction for nickel, a plus correction must also be added equal to 2(C − 54 + 0.06 Ni) if this figures to a positive quantity. (C and Ni are carbon and nickel con-

Upper Critical Temperatures (Iron-Carbon System)
According to Different Authorities

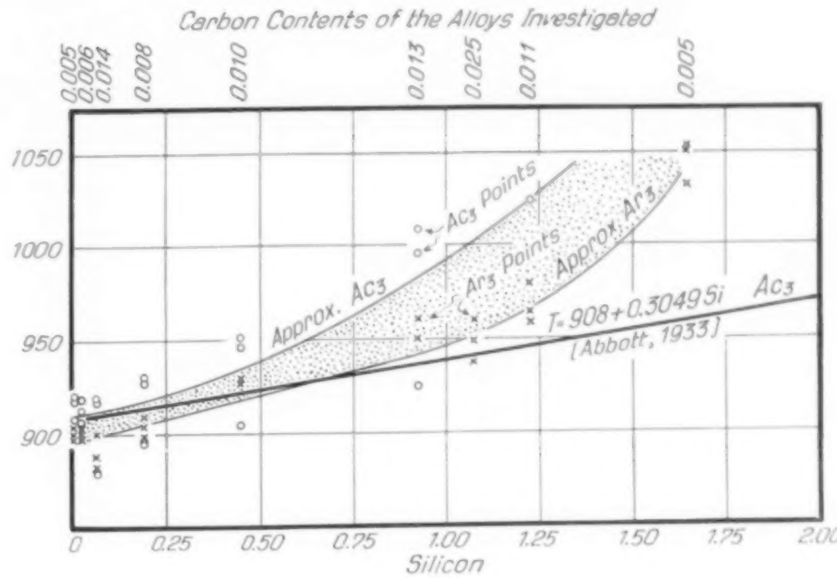


tents expressed in units of 0.01%.) Sulphur and chromium had no effect on Ac_3 of the steels examined by Mr. Abbott.

As anyone who will take the trouble to check this against accurate figures for Ac_3 on S.A.E. steels will find, it will give reliable results. Computations based on mill analysis will locate Ac_3 close enough for any shop operation that requires to know the value of this temperature.

It will be noticed that the above corrections assume a linear relationship for the various elements, and it was interesting to plot the line for carbon and compare it with the lines on some widely accepted iron-carbon equilibrium diagrams. As shown at left, below, Mr. Abbott's line for carbon seems to be high. However, if commercial carbon *steels* are figured by his formula, their actual Ac_3 points usually fall within the stippled area of the sketch, because they ordinarily have more than enough manganese to counteract the elevating effect of phosphorus and silicon. It would appear, therefore, that the classical equilibrium diagram really shows the transformation of commercial *steels*, and the true iron-carbon diagram should have a flatter line for Ac_3 — about as figured by Abbott. In fact, workers on any of the binary iron alloys will welcome this formula as evidence as to the slope of the Ac_3 line at low concentrations.

Determinations on Very Pure Iron-Silicon Alloys
By Pilling & Halliwell, 1924



Most theorists would criticize his assumption that such a line is straight. More than likely it would be curved. Thus, the accurate determinations by Pilling and Halliwell on pure iron-silicon alloys plotted above indicate a sharp up-turn (as is required by the well-known gamma loop). The straight line assumption for any element is only justified for fairly narrow ranges of composition, and for this range the true curve may be approximated by its tangent. In the case of silicon, nearly all S.A.E. steels have fractional percentages; consequently, the error in figuring by Mr. Abbott's straight-line formula rather than the more nearly correct curve for silicon is slight. It is only a happen-so that the entire formula for Ac_3 works out for the silico-manganese spring steels, and this is due to the fact that an error in figuring high silicon is canceled by an opposite error in figuring high manganese.

Likewise, the mathematical conclusion reached by Mr. Abbott that chromium has no effect on the Ac_3 point must be qualified in view of the known effect of chromium in making a gamma loop and producing stainless chromium-iron alloys with no transformations of any sort. However, it should be remembered that Mr. Abbott's formula applies only to steels containing perhaps 2% chromium as a maximum. Furthermore, Dr. Krivobok's latest iron-chromium equilibrium diagram shows the gamma loop to be formed principally by the depression of the Ac_4 point rather than an elevation of the Ac_3 point; consequently a horizontal course of the Ac_3 line for low chromium is probably correct.

Mr. Abbott's specimens were collected before molybdenum appeared as an important alloying element, consequently a problem awaits some metallurgical student to determine accurately the effect of fractional percentages of it on the common steels. A number of heating curves of analyzed molybdenum steels were found in the available literature and those upon which Ac_3 could be spotted with any assurance were corrected for the other elements according to the above factors. As a first approximation it would appear to the editor that 0.01% molybdenum lowers Ac_3 by about 0.6° C.

DESIGN AND AESTHETICS

of assemblies using welding

By Robert E. Kinkead
Consulting Engineer, Welding
Cleveland

WELDING IS INCIDENTAL TO THE design of structures. It is merely a useful method of assembling pieces of metal to form a structure of predetermined size, shape, and service life. On the other hand, it permits us to design and construct metal assemblies which most nearly satisfy our economic necessities and artistic sense of the fitness of things. Designers can yield nothing from this creed which demands that they satisfy economic necessities and also an artistic sense of the fitness of things.

If we think of a pipe line to convey oil from Texas to Chicago, the ideal solution is at once a continuous tube, smooth on the inside. That ideal conception existed long before we could weld a steel pipe line between Texas and Chicago; the welding process merely made it possible to realize an ideal. But the *use* of that particular process did not occur until the desired pipe line could be made welded for less cost than by any other method.

Another instance will suffice to illustrate the point. It has been known for many years that the ideal container for large volumes of gas under pressure is a hollow sphere. The illustration opposite shows such a container. Any other way of constructing a pressure gas holder will cost more. Any other shape of holder for the purpose will be less satisfying to our artistic sense.

In building construction involving the use of structural steel, the continuous beam has the advantage of carrying the most load per pound of material within the limits of permissible deformation. *That* was a conception which antedated welded construction by many years. Use of welding as a constructional method has made it possible. In this instance, the economic necessities have obviously been met. It may be contended that this case has little relationship to artistic conceptions, but if a digression were permitted from the practical details of design into the realm of philosophy of design, the continuous beam in buildings, bridges, and other structures may be shown to be necessary from the artistic point of view.

There is a symmetry, a harmony and a rhythm to creative design. The supposed line of demarcation between pure art and pure science disappeared some years ago. There never was such a line of demarcation — it existed only in our imaginations. The design of a machine, a building, a ship — in fact any structure composed of metal parts — is a creative art. Those who have been out of college 20 years will recall

that we were taught that such design consisted entirely of an application of known formulas, most of which were printed in the handbook. How eternally wrong that conception was is adequately demonstrated by the crudeness and inadequacy of many structures designed and built 20 to 30 years ago.

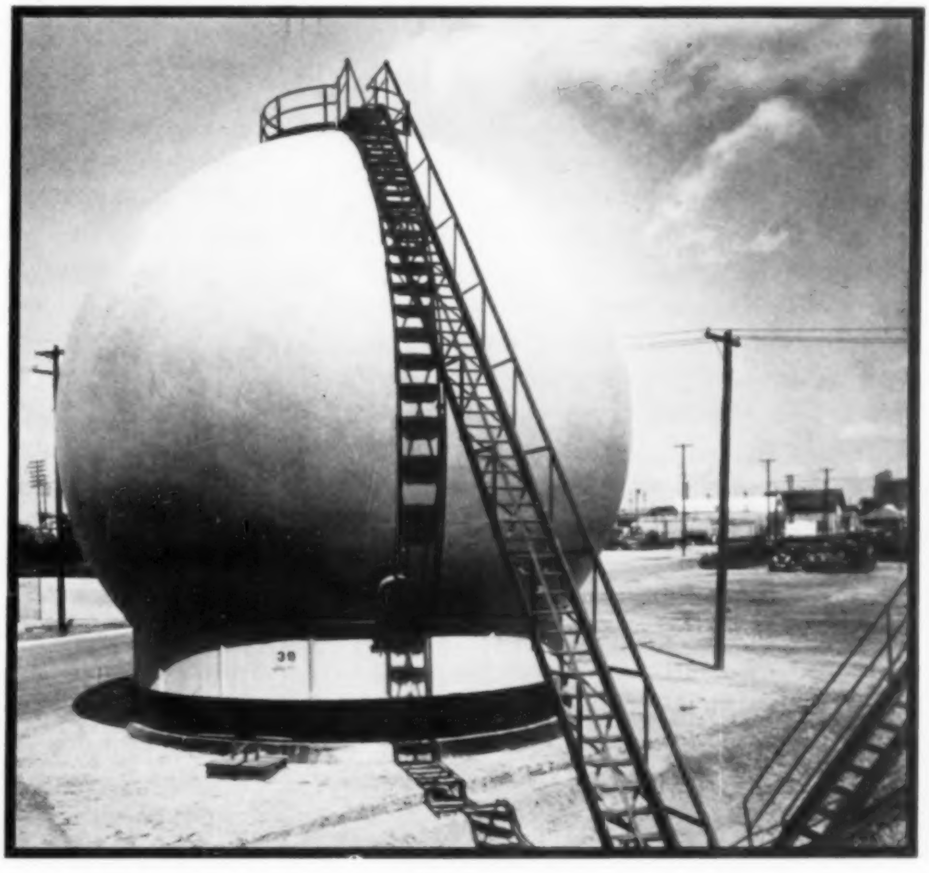
Design as a creative art cannot be practiced by inhibited or inharmonious minds. We cannot compromise with our artistic sense of the fitness of things and still have the spirit to do creative work. If we lose that sense, we go back to the days of engineering handbook design in which our final product becomes a hodge-podge proclaiming to the world the degree of our intellectual dishonesty and moral cowardice.

The philosophy of creative design of metal structures is now receiving long-delayed recognition. Many welded structures in common use illustrate the absolute honesty of purpose of the designers. Structures like the new high speed, light weight passenger trains which are welded of metals represent creative art. Stream-lined automobile bodies, aircraft, and motor boats are rapidly being redesigned to meet the new concepts of construction.

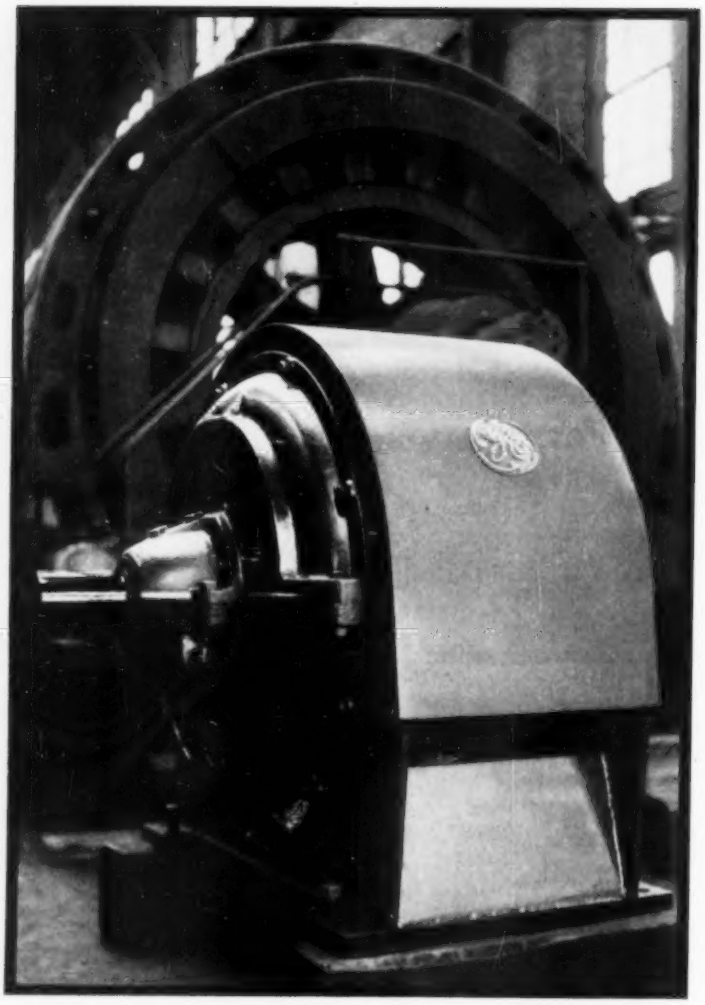
No better illustration may be found than the new 10,000-ton cruisers now on the ways. These war ships are 40 to 60% welded, and later ones will be 100% welded as soon as the shipyards develop the necessary technique. But in the *conception* of the designers, they are 100% welded now. They were confronted with the problem of getting the most advantageous combination of speed and gun power on these vessels whose displacement was limited by existing treaties. That singleness of purpose was maintained with absolute integrity within the limits of the ability of the existing yards to build to the designs, and that singleness of purpose has resulted in ships with beauty of line and correctness of detail which is completely satisfying to one's artistic or æsthetic sense.

It will be recalled that a digression into the philosophy of creative design would show that the use of a welded continuous beam might be required to meet our artistic sense. If the welded continuous beam meets the economic necessities, it is fully justified by our artistic sense — for the reason that continuity is the outstanding characteristic we strive for in any metal structure. The ideal steel structure for any building is a continuous metal frame in which all of the metal is of such a character as to meet completely the necessities at each particular point in the structure. Therefore, the idea of continuity is basic and fundamental, and to disregard it is to introduce disharmony into the concept of the design.

This leads immediately into a consideration of the yardstick by which we can measure



"Hortonsphere," 38 Ft. Diameter for Holding Fluids at 50 Lb. Pressure. Butt-welded construction by Chicago Bridge & Iron Works for Empire Refining Co.



Welded Frame, by General Electric Co., Combines Utility and Good Looks

the intangible which I have been referring to, namely, our artistic sense of the fitness of things. (As engineers, we can tell immediately whether or not a metal structure satisfies what we frequently call our mechanical sense.) It is not sufficient to say that it is an indefinable sixth or seventh sense and that we just "know" whether the structure is satisfying or not. As engineers, we get paid for designing structures which will produce that satisfying effect on other people, and that result must be predictable.

We know what the above-mentioned yardstick is: It is the mathematical correctness in the dimensions of length, breadth, thickness, and time. And we must face the implications of using this method of measurement. We must not paint a piece of welded steel machinery red merely because we like red paint. We must not add to or subtract from a welded steel structure "for the sake of appearance." That way of doing it does not lead to a predictable result. The term, good appearance, is too relative and involves uncertainties to such a degree as to make it likely that what the designer recognizes as good appearance will not be so recognized by others. However, if the structure is of mathematically correct design, it will have a good appearance to the largest number of people, since beauty of line and form come from mathematical correctness.

Nature has known these things for a long time — man is just learning them. Thus, if you wish to design a long, slender flag pole, study a bamboo pole; nature arrived at the correct solution of that problem through millions of years of trial and error! There is more to be learned of structural design in the bones of animals, birds, and fish than in all the books that have ever been written on the subject. Nature is the source of all information about design. Nature is continually experimenting with new designs and solving problems by trial and error.

If we are to hew to the line in the matter of correctness of design as a method of producing structures of satisfying appearance, we will perhaps arouse some misgivings in the minds of young designers about surface finish, but there is no basis for such doubts so long as we are learning our tricks of design from Nature. The most gorgeous flower that ever bloomed is merely an artful lure to bees. Nature knows about competition. She did not design orchids for Junior Proms. She designed that flower of exotic beauty and fragrance to get the attention of a worker bee whose legs were covered with fertilizing pollen from some other orchid. It just happens that humans appreciate the beauty of orchids. Beauty arises from utility.

So we are perfectly safe in basing all of our design on the foundation of mathematical correctness for the purpose for which the product of design is to be used.

If there appears to be undue emphasis on design of welded structures as a creative art, it is because there exist some examples which fall short of either economic or artistic justification. Welded structures fail prematurely if

they are not designed properly. Such failures may cause loss of life, property damage, or both. Since failure to design a structure so it will give the required service is far oftener due to the lack of a clear and sound conception of basic principles of engineering design than it is to defects of the technique of design and draftsmanship, we may emphasize that an outline of the general plan one should follow in designing a welded steel structure is most desirable.

In this article of his series on engineering aspects of welding, Mr. Kinkead takes the stand that mathematically correct design as to space dimensions and time will completely satisfy the aesthetic senses. Welding promotes this end, for it removes many limitations of former methods of construction

The first step in the necessary planning is to state *in writing* the complete service requirements to be met. It is most dangerous to shirk this duty. It is analogous to writing the specifications of the job to be done.

Among other things, this clearly involves a statement of the service life of the structure, since it might be entirely different if the required life is three years than though the required life is 20 years. (Nothing lasts forever.) In certain classes of machinery, the life may be expressed in terms of cycles of operation; in the case of automobiles, miles the car may be driven; bridges, in terms of calendar years; warships, in terms of minutes of action in battle. In the case of the structure under consideration, a clear conception must be obtained of factors which will operate to shorten the life of the structure. Fatigue, corrosion, and abrasion are examples of such degenerative influences.

While designers whose principal source of inspiration is an engineering handbook may not be expected to know it, there is a general disposition among capable engineers to insist that structures should have a service life at least as long as is required to amortise the bonds issued to pay for the work. To do otherwise would be to descend to the level of highway departments that design and build roads which wear out and have to be replaced twice before the first bond issue is amortised! Lest such remarks be considered facetious, it should be recalled that there is excellent statistical evidence that very, very little heavy engineering equipment, automobiles, or domestic appliances are being bought by cash across the counter.

It is often valuable to construct a space-force diagram in which the direction and magnitude of all of the forces are shown and the space relationship of the several operating forces established. Having such a diagram or model, we may suggest a disposition of metal to resist the operating forces. We say *suggest* advisedly, because the first approximation of how the metal shall be disposed to resist the operating forces will in most cases be subject to radical modification.

As has been said before, *continuity* is an ideal to be approached in the design of any metal structure. A casting certainly meets that ideal. But castings do not always meet the economic necessities. In many cases not involving mass production, the cost of using castings is too high, so in the design of the welded metal structures, we propose to put together individual pieces of metal and weld them into a continuous and harmonious whole. The problem is one of cutting and forming these individual pieces so that they satisfy this basic requirement when they are welded together. For machinery, automobiles, ships, and similar construction we are generally driven to the use of formed plate and tubes, for it is usually difficult to get a sufficiently close approximation of what we want from structural shapes, originally designed for riveted construction on bridges and buildings.

Welded structures may be entire assemblies of parts which have been cold pressed and welded together. The number of structures to be made will determine how far we can go in the direction of making dies for the presses, and will also, to a considerable extent, determine the welding process we use. In many cases, welded structures are made up of parts which have been formed on a *(Continued on page 52)*

LETTERS AND COMMENT

Nital Etch for Macrostructure

PHILADELPHIA, PA. — In checking over published lists of etching methods for revealing the macrostructure of steel, we were surprised to find that 5% nital has been scarcely mentioned.

At SKF Research Laboratory we have found this to be extremely valuable, especially for heat treated pieces. The procedure is first to clean the piece thoroughly with gasoline, wash with alcohol, and etch for about 5 min. in 5% nitric acid in alcohol. On removal from the solution, the piece will be covered with a film of black sludge (largely carbides) which is washed or scrubbed off with a soft rag moistened in alcohol. The piece is next immersed in a 10% solution of hydrochloric acid in alcohol for a few seconds merely to clean it up and increase the contrast.

Troostite spots in martensite, ferrite areas, tempering from improper grinding, or other inhomogeneities in the structure are clearly shown. On standing for about 15 min. after etching, the very finest cracks are revealed by the acid working out by capillarity.

This etch is non-destructive and removes only a small fraction of a thousandth of an inch from the surface of most steels.

H. O. WALP

Dr. Giolitti Summarizes His Knowledge About Flakes

TURIN, ITALY — While I completely agree with many essential points developed in the very interesting article on "Flakes in Alloy Steels," by H. H. Ashdown, in the November issue of METAL PROGRESS, there are some points on which my opinions differ.

During the three years prior to the War and during the War, I had especially good opportunities for a practical study of this problem, as the Ansaldo Steel Works (of which I was general superintendent) turned out more than 10,000 guns of all calibers from 3 in. to 16 in. This certainly was nearly, if not actually, the largest production of ordnance by any existing factory in those years.

During the whole period, I acquired a considerable number of facts, which can be briefly summarized as follows:

1. Contrary to the observations of Mr. Ashdown, we always found that the cleanest steels (we made them mostly in acid-lined furnaces) melted and refined with the greatest care, and showing superior physical properties when tested in a direction transverse to the greatest compression during forging, were practically immune from flakes.

2. I could never find a single instance where hairline cracks could be detected by the most careful search on the polished surfaces of gun forgings, either externally or in the interior of the bore. This statement is also true for steels which developed conspicuous flakes on the surface of fractured test pieces cut from finished forgings.

3. The development of flakes in test pieces may depend in a noteworthy degree upon the testing procedure — slow deformation usually favoring the formation of flakes.

4. In cases where flakes are not too frequent or too developed, a proper heat treatment can completely cure the disease. For obvious reasons of brevity I cannot discuss this statement here in detail.

5. In really clean and carefully made steels we never had flakes even though the forgings were cooled on the floor (a practice to which Mr. Ashdown strongly objects, as it is, in his opinion, a prime cause of flakes). This oc-

curred rather often, on account of the great urge for production during the War. "Clean steel," in the above sense, is a steel which not only appears free from the impurities detectable by microscopic and macroscopic investigation, but is also exempt from the so-called "emulsified inclusions," and which shows approximately the same physical properties in the transverse and longitudinal directions after forging and heat treatment.

Taking into consideration these facts (which I have developed in several articles published principally in Italian and German journals) my opinion on the origin of flakes may be stated briefly as follows:

I agree with Ashdown's statement that flakes must be born after forging, but I do not think that this occurs *immediately* after forging, and *simply* as a consequence of intercrystalline cooling stresses, without being influenced by impurities in the steel. On the contrary, I believe that the intercrystalline stresses (originated by allotropic changes during cooling) do not cause the slightest internal crack when the impurities in the steel are below a certain very low limit. This is proved by the facts pointed out above as paragraphs 1 and 5. Only in very impure steels (such as I never met in the manufacture of guns) can the cracks develop immediately after forging by the simple effect of cooling (see point 2). In steels of medium purity the cracks are formed when the cold metal is submitted to sufficient stress, whereupon the impurities (accumulated in what were the intercrystalline joints before the heat treatment) yield locally, and act as starting points for cracks. This explains the facts I have quoted above in paragraphs 2 and 3, and also the remarks in paragraph 4, since, as is well known, some impurities may be caused to diffuse during proper heat treatments.

It is evident that all the facts I have quoted in 1 to 5 could not be explained by Ashdown's hypothesis that the cracks corresponding to the flakes (or, rather, *being* the flakes themselves) are formed, even in very pure steels, by the simple effect of cooling after forging, and are in existence before the external strains are imposed — such as by a testing machine — to fracture the entire piece and thus expose a surface upon which the flakes are observed.

Leaving aside the very impure steels, in which cracks may actually take place by the simple effect of too rapid cooling after forging, my opinion (based on the facts I have quoted before) is briefly that flakes are formed only when the cold steel is submitted to a sufficient strain, and they correspond to the planes of weakness in which impurities have accumulated during the original crystallization of the steel ingot.

Of course, a rapid cooling after forging may increase — and a slow cooling decrease — the local tensions on the weak places where flakes are formed at a later moment, when the cold metal is submitted to mechanical strains.

In this case of very impure steels — but only in this case — I agree with Mr. Ashdown's view that cracks can form immediately after forging. I may add that many years ago I had the opportunity of studying a few very large nickel steel forgings in which the facts quoted by him were exceptionally well developed. The results of that study were published in 1915 in *Industria*, and are quoted in part in my volume on "Heat Treatment of Soft and Medium Steels," pages 147 to 151. FEDERICO GIOLITTI

Gear Hardening With Oxy-Acetylene

HUDDERSFIELD, ENGLAND — Considerable interest is being shown in Great Britain in the surface hardening of gear teeth about the pitch line by an oxy-acetylene flame. The hand-operated process of localized hardening is by no means new, having been practiced for at least 20 years, but was never developed widely owing to the variability which was likely to occur even with skilled workmen. Introduction of a machine about four years ago to give mechanical control of the process revived interest, and now that sufficient service results on varied work have accumulated, its uses are spreading.

For gears too large for quenching or case hardening, it provides a means whereby a wearing surface of from 450 to 700 diamond Brinell can be obtained. Since parts so treated undergo little or no distortion, it is valuable also for medium sized work.

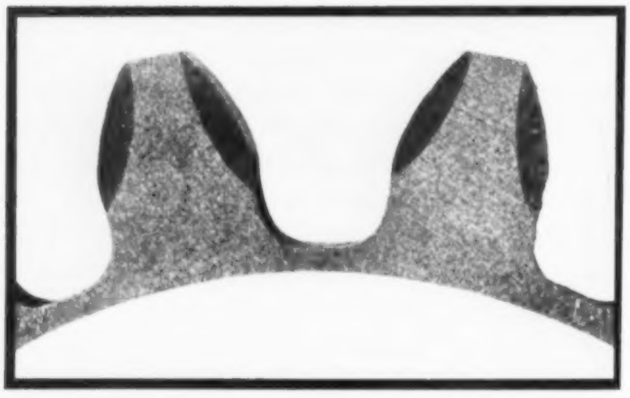
Briefly, the machine consists of a suitable tank wherein the gear is immersed up to the center in water (helical or bevel gears being

suitably canted) to leave the surface of one tooth flush with the cooling liquid. An oxy-acetylene blowpipe of special design is attached to a motor-driven head, so arranged and the controls so set that the flame travels at a predetermined speed over the exposed face of the tooth. The slower the travel, the greater the depth of hardening and vice versa. A jet of water (or in certain cases nitrogen) following the blowpipe quenches the heated surface so that as the blowpipe travels one sees a moving area of steel raised to quenching temperature and being immediately cooled.

A simple indexing device pitches the gear wheel round after one surface of one tooth has been hardened, and when one side of all the teeth have been hardened the gear is reversed to do the other side, unless it is to run in one direction only in service.

Suitable stops and valves combined with a small pilot flame cause the blowpipe to ignite immediately the tooth surface is reached, and to be shut off as soon as the blowpipe has finished its traverse of one tooth, thus economizing in gas. The blowpipe incorporates one to five jets, depending on the pitch of the gear. Machines have been developed to harden gear teeth ranging in size from 7 diametral pitch to 1 diametral pitch. Other devices are attached and other modifications are possible to suit varied requirements of parts other than gears which are desired to be hardened in certain regions only.

The steels used range from 0.40% carbon steel to 0.65% carbon steel, and include practically all of the engineering alloy steels. It has latterly been extended to cast iron, and the



Full Size View of Gear Teeth, Sectioned and Etched, to Show Depth of Hardening by Automatic Oxy-Acetylene Flame

writer has just supervised the treatment of a double helical wheel of this material, 11 ft. diameter, 16 in. face, 220 teeth.

In a properly treated gear, the depth of hardening should be similar to that shown in the accompanying macrograph. The greatest depth of hardening on the pitch line can be varied from 0.020 to 0.15 in., and without serious grain growth of the outer layers.

In general the hardness — 450 to 700 — is greater than that which can be obtained from the same steel by a full water quench. While for sheer wear resistance and general load carrying capacity, the writer would not say the process rivaled that of case hardening, the method does fill a very wide and useful field.

Francis W. Rowe

Duplex Refining Process

PARIS, France — Numerous and voluminous studies have been published during recent years on the application of thermodynamics to reactions between melted steel and slag — reactions which are the fundamentals of metallurgical processes. Their authors have undertaken lengthy mathematical speculations based on a comparatively small number of analyses of slags and baths sampled at various temperatures. However, the application of such mathematical expressions requires that chemical equilibrium be attained — a matter of great uncertainty as yet. In fact, we have no experimental data on the *speeds* of reaction between metal and slag, though this be the principal factor in metallurgical reactions.

Such speeds must be known in order, first, to obtain the conditions necessary to reach equilibrium, and secondly to apply the thermodynamical equations. If equilibrium could really be obtained, the composition of the metal at a given temperature could be determined from the slag analysis and vice versa, whereupon uniform production could be guaranteed.

The speed of reactions between liquid metal and slag depends on several variables such as the chemical composition of the two phases and their relation to the equilibrium composition, the fluidity of these phases, the area of the contact surfaces, and the stirring movements within slag and metal. The extent of the inter-

facial area and the stirring appear to be the most important variables. Reactions are almost instantaneous on the very contact surface between phases; any stirring action is vastly more important than movement by diffusion, which otherwise is the principal factor for obtaining equilibrium throughout metal and slag.

Naturally, the surface in contact may be greatly extended by puddling or any mechanical mixing of two phases, especially when an emulsion is obtained. For example, if a slag layer of height h is dispersed into the metal under the form of small spherical drops of diameter e, the contact surface is then multiplied by $6 \times h \div e$; for $h = 10$ cm. and $e = 1$ micron (the dimension of an emulsion) the area of the surfaces in contact is multiplied by 600,000.

These two variables, contact surface and stirring, depend upon the fluidity of the phases; in the case of great viscosity, diffusion and the motion inside the two phases are very much retarded — moreover, it is impossible to enlarge greatly the area in contact by stirring.

The above variables are quite different according to the metallurgical processes employed, with the result that the speeds approaching equilibrium may vary enormously. As yet, these relationships can be mentioned only in a qualitative way, for want of precise data.

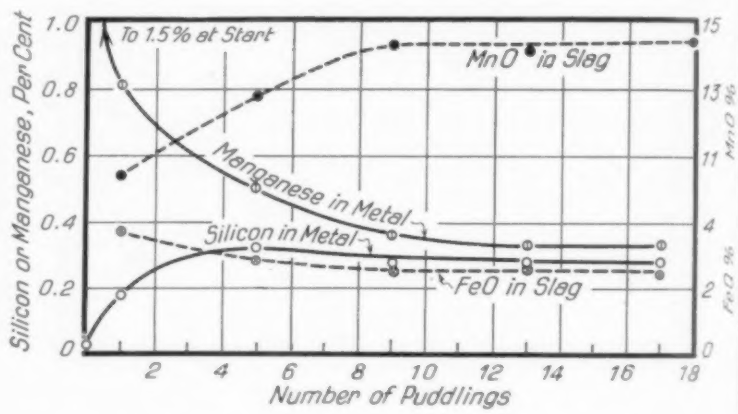
In converter operations a violent mixing of the phases occurs; the contact surface is considerably enlarged even though the slag becomes very fluid only after the temperature is raised by heat evolved by the reactions; the reaction is consequently very rapid and the operations may be halted at a defined chemical composition of the metal.

In the open-hearth processes the contact surface is much constricted; no puddling of the two phases occurs during long periods; the slag is kept rather viscous to avoid scouring the linings during the long operation; therefore, the reactions are slow.

Speed of reaction in the arc furnace is greater owing to the higher slag temperature.

In the induction furnace the liquid metal is stirred magnetically, which phenomenon increases the rate of exchange with the slag, but the surface contact is still smaller than in the open-hearth; the slag is heated only by the metal and remains, consequently, cooler and less fluid. However, reactions may be fast owing to the motion within the melted metal. Campbell observed (in a high frequency furnace with an oxidizing slag) carbon losses of 0.6% in 14 min. and 2% in 45 min., and also a phosphorus drop of 0.1% in 20 min.

Much greater speeds of reaction are obtained by intimately mixing slag and liquid metal, by means of a strong puddling action, thus providing an emulsion of the two phases. In such conditions more than 0.1% phosphorus has been eliminated with an adequate slag in less than 1 min., during which time equilibrium of the two phases is practically attained. This may be compared to what happens during overblowing in the basic bessemer. As for deoxidation, the diagram shows that with a suitable

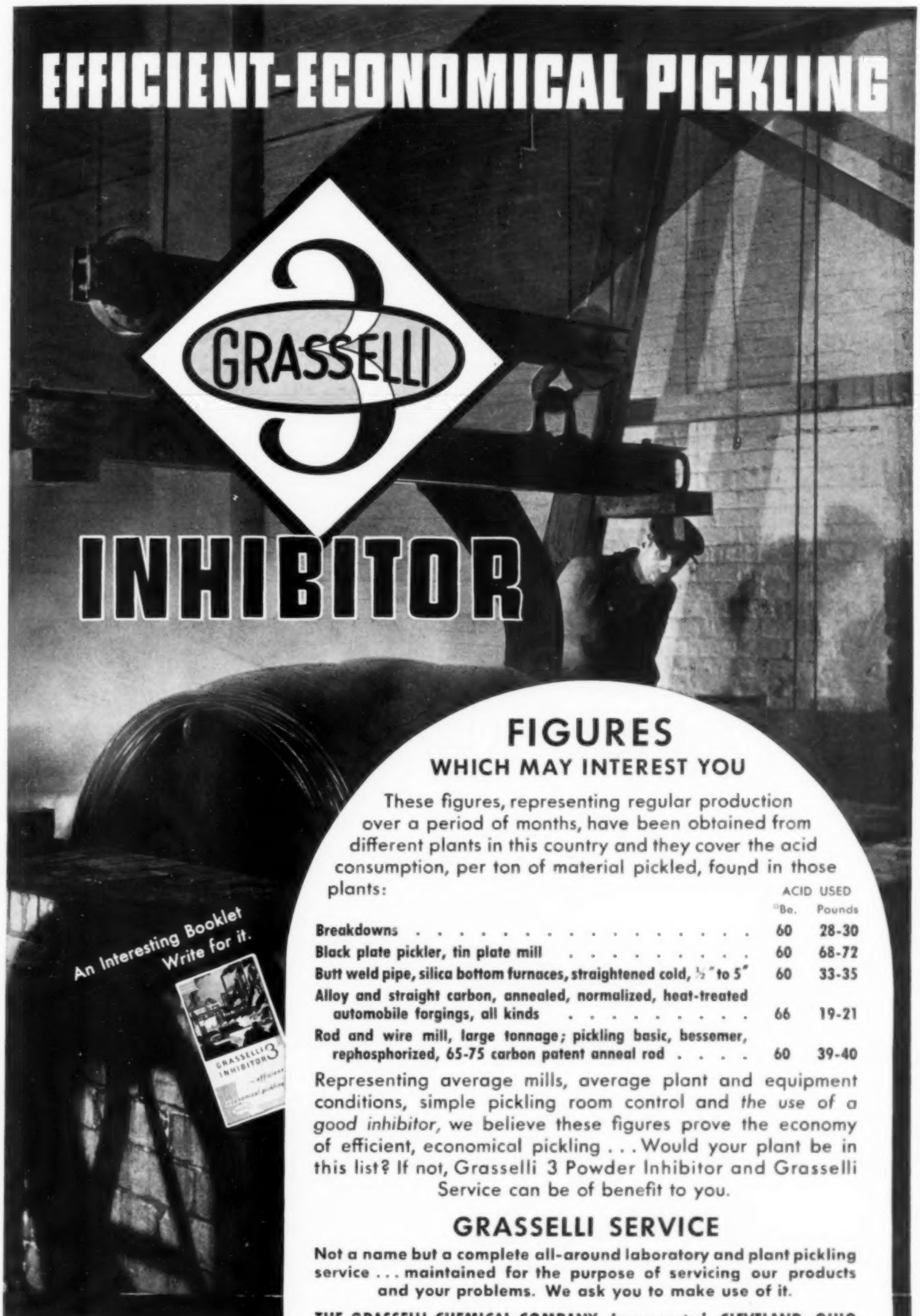


Change in Distribution of Manganese and Silicon, Slag to Metal, After Repeated "Puddlings by Impact"

slag (in the present case, 44% SiO_2, 8.5% TiO_2, 13.5% Al_2O_3, 6% CaO, 12% MgO) equilibrium is practically reached at ten puddlings by impact, in a total time of no more than 70 sec.! Equilibrium with the same slag is not attained after 15 min. when the operation is undertaken in a high frequency furnace.

It may be concluded that the quickest speed of decarburization is realized in the converter, whereas deoxidation is most rapidly done by the new emulsion processes — puddling the liquid metal with the fluid slag, a process we have already mentioned, just a year ago, in the February number of Metal Progress. A combination of these two operations in the form of a duplex process will certainly obtain the maximum of speed and precision.

Albert Portevin



FIGURES

WHICH MAY INTEREST YOU

These figures, representing regular production over a period of months, have been obtained from different plants in this country and they cover the acid consumption, per ton of material pickled, found in those plants:

	ACID USED °Be.	ACID USED Pounds
Breakdowns	60	28-30
Black plate pickler, tin plate mill	60	68-72
Butt weld pipe, silica bottom furnaces, straightened cold, ½" to 5"	60	33-35
Alloy and straight carbon, annealed, normalized, heat-treated automobile forgings, all kinds	66	19-21
Rod and wire mill, large tonnage; pickling basic, bessemer, rephosphorized, 65-75 carbon patent anneal rod	60	39-40

Representing average mills, average plant and equipment conditions, simple pickling room control and *the use of a good inhibitor,* we believe these figures prove the economy of efficient, economical pickling . . . Would your plant be in this list? If not, Grasselli 3 Powder Inhibitor and Grasselli Service can be of benefit to you.

GRASSELLI SERVICE

Not a name but a complete all-around laboratory and plant pickling service . . . maintained for the purpose of servicing our products and your problems. We ask you to make use of it.

THE GRASSELLI CHEMICAL COMPANY, Incorporated, CLEVELAND, OHIO

THINGS TO READ

Furnaces, Melting and Refining

Steel Making Progress in 1934, C. H. Herty, Mining & Metallurgy, Jan., p. 32; E. F. Ross, Steel, Jan. 1, p. 121. . . . . Standardization of the Refining Period, F. W. Sundblad, Iron Age, Jan. 25, p. 17. . . . . Progress in Crucible Melting, G. S. Watson, Metal Industry, Jan. 12, p. 66.

High Frequency Induction Furnaces, J. C. Hodge, Electrical Engineering, Jan., p. 194; G. R. Webster, Iron & Coal Trades Review, Jan. 5, p. 17. . . . . Rocking Indirect Arc Electric Furnaces, E. L. Crosby, Electrical Engineering, Jan., p. 132. . . . . Application of Solid Fuel to Non-Ferrous Furnaces, John Fallon, Metal Industry, Jan. 12, p. 63. . . . . Vacuum Furnaces, N. A. Ziegler, Metals & Alloys, Jan., p. 5.

Rolling, Forging, Drawing

Properties of Sheets as Influenced by Rolling and Annealing, C. A. Edwards, Iron & Coal Trades Review, Dec. 15, p. 903. . . . . Methods of Rolling Sheets, F. L. Estep, Iron Age, Dec. 28, p. 14. . . . . Electrical Control of Strip Mills, P. L. Alger, General Electric Review, Jan., p. 27.

Technique of Heavy Forging, R. Benson, Mechanical World, Dec. 8, p. 1183.

Analysis of the Wire Drawing Operation, (A series on Plastic Flow), Erich Siebel, Steel, Jan. 22, p. 30. . . . . Wire for Cold Heading, A. B. Arganbright, Wire, Jan., p. 10. . . . . Grain Size in Relation to Cold Working, Metal Industry, Dec. 22, p. 609. . . . . Pressures for Forming Operations, C. W. Lucas, American Machinist, Jan. 3, p. 24. . . . . Deep Drawing Sheet Steel, L. B. Hunt, Automobile Engineer, Jan., p. 25.

Alloy Cast Iron Dies for Stamping and Pressing, Inco, Jan., p. 14. . . . . Costs of Nitrided Dies, G. Powis, Metallurgia, Dec., p. 38. . . . Spalling of Corners on Nitrided Dies, Bernard Thomas, Heat Treating & Forging, Dec., p. 93. . . . . Improvements in Forging Dies, E. F. Ross, Steel, Jan. 1, p. 123.

Manufacture of Non-Ferrous Seamless Tubes, Gilbert Evans, Wire & Wire Products, Jan., p. 17; Engineering, Jan. 12, p. 30. . . . . Layout of Plant for Butt Weld Pipe, J. B. Nealey, Wire & Wire Products, Jan., p. 7; Steel, Jan. 8, p. 21.

Properties & Uses

A series of papers relating to Creep, read before American Society of Mechanical Engineers, by A. Nadai (2), E. L. Robinson, G. H. MacCullough (2), P. G. McVetty, H. C. Cross. . . . . Metallurgical Problems of 1000° Steam Stations, Power Plant Engineering, Jan., p. 4, 16.

Tensile Properties of Various Alloys at Liquid Hydrogen (—253° C.), by W. J. De Haas and Sir Robert Hadfield, Philosophical Transactions of Royal Society, Vol. 232, p. 297. . . . . Mechanical Properties of Non-Ferrous Metals at Low Temperatures, E. W. Colbeck, Metal Industry, Dec. 15, p. 579.

New Materials for Chemical Equipment, W. R. Huey, Industrial & Engineering Chemistry, Jan., p. 10; S. Wernick, Industrial Chemist, Dec., p. 445. . . . . Stainless in the Food Industries, S. H. Phillips, Western Machinery & Steel World, Jan., p. 12. . . . . Properties of 18-8 Wire, W. H. Wills, Transactions, American Society for Metals, Jan., p. 1. . . . . Heat and Acid Resisting Alloys, J. F. Kayser, Foundry Trade Journal, Jan. 11, p. 26. . . . . Sulphide Corrosion in Gasoline Refineries, J. C. Albright, National Petroleum News, Jan. 24, p. 29. . . . . Pipe Corrosion and Pipe Protection, A. H. Abbott, American Gas Journal, Jan., p. 9. . . . .

(Continued on Page 46)

Embrittling of Steels, A. M. McKay, Engineering, Dec. 15, p. 647.

Steel for Permanent Magnets, R. L. Dowdell, Transactions, American Society for Metals, Jan., p. 19. . . . . Burglar-Proof Steels, E. A. France, Steel, Jan. 15, p. 21. . . . . Electrical Metal Production, H. Williamson, Electrical Review, Jan. 5, p. 4.

Heat Treatment

Alloy Steels and Heat Treatment During 1934, Jerome Strauss, Mining & Metallurgy, Jan., p. 33. . . . . Electrical Heat in Industry, A Review, Electrical World, Jan. 6., p. 51; also P. L. Alger, General Electric Review, Jan., p. 30.

Quenching Rates Under Various Conditions, Howard Scott, Transactions, American Society for Metals, Jan., p. 68. . . . . Time Required to Heat Slabs, J. D. Keller, Heat Treating & Forging, Dec., p. 100. . . . . Heat Treatment of Tool Steel, J. C. Alexander, Mechanical World, Dec. 8, p. 1175; F. W. Rowe, Machinery (England), Dec. 21, p. 347. . . . . Hardening Transmission Gears, Burnham Finney, Iron Age, Jan. 18, p. 12. . . . . Heat Treating and Reforming Rail Ends, C. A. Daley, Industry & Welding, Dec., p. 3; Steel, Jan. 22, p. 27.

Temperature Regulation; Theoretical Principles, A. Ivanoff, Iron & Coal Trades Review, Dec. 22, p. 945.

Control and Measurement of Temperature, E. A. Cooke, Chemistry & Industry, Dec. 22, p. 1031.

Controlled Atmospheres in Heat Treating, E. F. Ross, Steel, Jan. 1, p. 126; W. W. Young, Gas Age-Record, Jan. 20, p. 56. . . . . Bright Annealing of Steel Blanks, M. W. Brewster, Machinery, Jan., p. 265. . . . . Surface Decarburization by Hydrogen and Steam, C. R. Austin, Transactions, American Society for Metals, Jan., p. 31. . . . . Hydrogen Nitrogen Atmospheres for Heating Non-Ferrous Metals in Electric Furnace, R. F. Benzinger, Heat Treating & Forging, Dec., p. 105. . . . . Furnaces for Heat Treatment, W. A. Thain, Aircraft Engineering, Jan., p. 13.

Non-Ferrous Metals & Alloys

Smelting and Refining Non-Ferrous Metals, and Their Physical Metallurgy; A Series of Reviews of Progress in 1933, Mining & Metallurgy, Jan. Issue. . . . . Recent Continental Progress in Non-Ferrous Alloys, Metal Industry, Jan. 12, p. 61. . . . . The Future of Secondary Metals, J. W. Furness, Engineering & Mining Journal, Jan., p. 11.

The Aluminum Industry, G. A. Anderson, Metal Industry, Jan. 12, p. 41. . . . . Aluminum Losses in Melting, W. Ashcroft, Metallurgia, Dec., p. 42. . . . . Electron and Hydronalium (Mg-Al), W. Schmidt, Chemical Age, Jan. 6, p. 4. . . . . Magnesium Alloys for Aeronautics, L. Aitchison, Metallurgia, Dec., p. 49. . . . . Corrosion of Magnesium Alloys, G. D. Bengough, Aircraft Engineering, Jan., p. 7; Metal Industry, Jan. 5, p. 3.

Nickel Industry in 1933, R. C. Stanley, Iron & Coal Trades Review, Jan. 12, p. 51; A. C. Sturney, Metal Industry, Jan. 12, p. 46.

Impurities in Commercial Zinc, Werner Frölich, Metal Industry, Dec. 8, p. 559.

Hardenable Copper Alloys Containing Nickel and Aluminum, H. W. Brownsdon, (Paper for British Institute of Metals), Engineering, Dec. 22, p. 695. . . . . Beryllium-Copper Castings, E. F. Cone, Transactions, American Foundrymen's Asso., Dec., p. 330. . . . . Deoxidation and Degasification of Bronze Castings, Transactions, American Foundrymen's Asso., Dec., p. 370. . . . . Inverse Segregation in Bronze Castings, O. W. Ellis, Transactions, American Foundrymen's Asso., Dec., p. 347. . . . . A Study of Six Bearing Bronzes, O. E. Harder, Transactions, American Foundrymen's Asso., Dec., p. 314. . . . . Castability of Ternary Alloys, A. Portevin, Journal of the Institute of Metals, Dec., p. 236. . . . . Deoxidizers and Fluxes, G. L. Bailey, Metal Industry, Dec. 8, p. 561.

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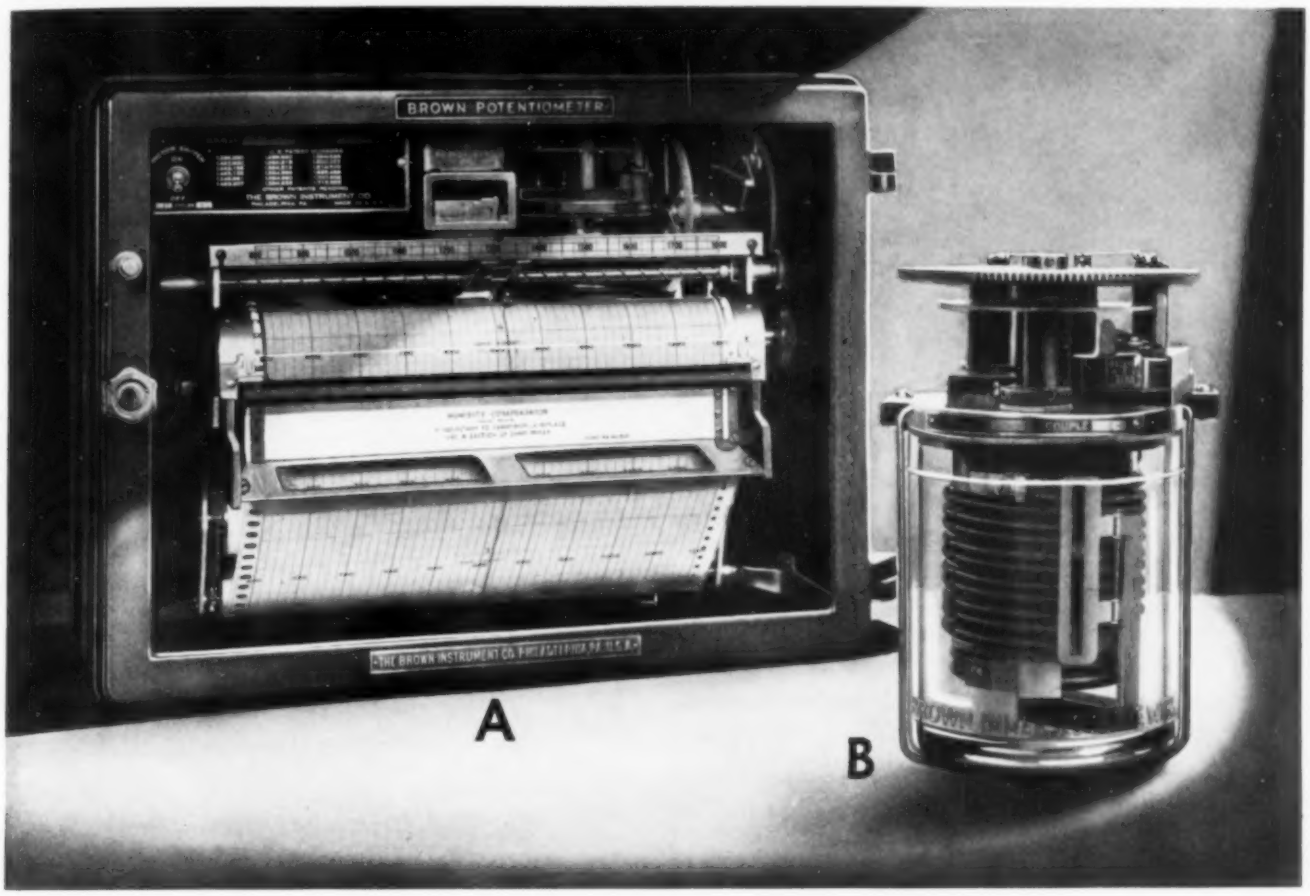

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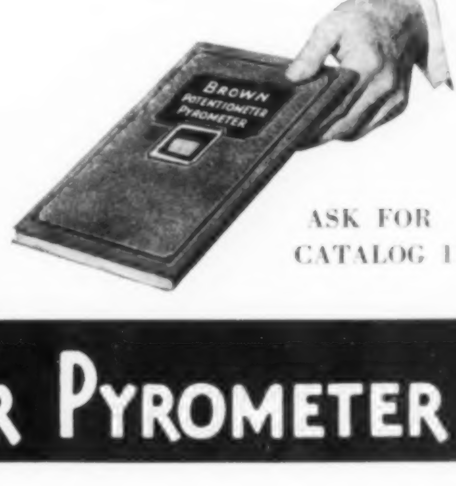

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BROWN POTENTIOMETER PYROMETER

Recent Progress in Die Casting, E. F. Ross, Steel, Jan. 1, p. 131; R. L. Davis, Machine Design, Jan., p. 33. . . . . Die Castings Vs. Stampings, Herbert Chase, Iron Age, Dec. 28, p. 26. . . . . Pressure Casting in Plaster Molds, Iron Age, Dec. 28, p. 32.

Iron & Steel Foundry

Cast Iron, Progress During 1934, J. T. MacKenzie, Mining & Metallurgy, Jan., p. 35; H. M. Lane, Iron Age, Jan. 11, p. 23. . . . . Recent Improvements in Steel Foundry Practice, R. A. Bull, Mining & Metallurgy, Jan., p. 36. . . . . A Metallurgist's Outlook on Modern Foundry Production, J. R. Handforth, Foundry Trade Journal, Jan. 4, p. 11. . . . . Need for a Classification of Foundry Steels, R. A. Bull, Metals & Alloys, Jan., p. 1.

Symposium on Cast Iron, 164-page book by American Society for Testing Materials and American Foundrymen's Asso. . . . . Cast Iron and Its Production, M. V. Healey, Electrical Engineering, Jan., p. 120. . . . . Gray Iron From Acid Electric Furnace, C. L. Frear, Transactions, American Foundrymen's Asso., Dec., p. 289. . . . . Production of Sound Iron Castings, Iron & Steel Industry, Dec., p. 75. . . . . Deoxidation of Cast Iron, W. F. Chubb, Metallurgia, Dec., p. 53. . . . . Strength Properties of Cast Iron, J. E. Hurst, Metallurgia, Dec., p. 43. . . . . Toughness of Hot Cast Iron, F. B. Dahle, Metals & Alloys, Jan., p. 17. . . . . Vanadium and Cobalt Additions to Cast Iron, J. E. Hurst, Iron & Steel Industry, Dec., p. 67.

Chromium Alloy Steel Castings, J. H. Critchett, Foundry, Jan., p. 16.

Malleable Cast Iron as an Engineering Material, C. C. Hodgson, Machinery (British), Dec. 7, p. 273. . . . . Malleable From Duplexed Cupola and Electric Furnace, C. B. Teeter, Iron Age, Dec. 28, p. 12.

Welding

Welding in 1933; Reviews by P. L. Alger, General Electric Review, Jan., p. 29; E. F. Ross, Steel, Jan. 1, p. 124; Factory Management & Maintenance, Jan., p. 29; Machinery (British), Jan. 11, p. 435.

Qualifying Tests for Welders, E. Lunn, (Paper for American Welding Society), Boiler Maker & Plate Fabricator, Jan., p. 18. . . . . Shop Practice in Welding, W. Gibson, Aircraft Engineering, Jan., p. 20. . . . . Navy Boiler Drum Practice for Fusion Welded Pipe, Boiler Maker & Plate Fabricator, Jan., p. 2. . . . . Standard Pipe Welding, John Zink, Industry & Welding, Jan., p. 6. . . . . Arc Welding of Galvanized Steel, L. C. Bibber, Journal, American Welding Society, Dec., p. 4.

Gas Welding of Aluminum, H. Herrman, Welding Industry, Dec., p. 347. . . . . Welding Rods for High Nickel Alloys, Inco, Jan., p. 17.

Nature of Arc Welded Metal (A Series), Robert Notvest, Welding, Dec., p. 535. . . . . Corrodibility of Welds by Alternate Immersion in HCl, F. R. Hensel, Metals & Alloys, Jan., p. 11.

Flame Cutting of Steel for Welded Joints, Welding Industry, Dec., p. 352.

Electric Resistance Welding, K. L. Nielson, Welding Industry, Dec., p. 341. . . . . Resistance Welding Control Devices, R. L. Briggs, Industry & Welding, Dec., p. 22. . . . . Timing of Spot Welders, (two articles), D. C. Wright and Carroll Stansbury, Journal, American Welding Society, Dec., p. 13 and 17. . . . . Automatic Controls for Electric Welders, H. W. Roth, Journal, American Welding Society, Dec., p. 10.

Construction of Pressure Regulators, G. M. Deming, Journal, American Welding Society, Dec., p. 22. . . . . Pressure Booster for Acetylene Distribution, C. S. Milne, Welding Journal, Dec., p. 365.

Welding for Pressure Vessels, Robert Sulzer, Transactions of the Institute of Marine Engineers, Dec., p. 257; Engineering, Dec. 22, p. 686.

WELDING DESIGN

(Continued from p. 37) bending brake. The job of determining how the individual pieces will be cut and formed is one which involves many more factors than it is possible to deal with here; in many cases, the designer will have to do what he can rather than what he would like. The degree of perfection he attains will be measured by the degree to which he is able to meet the economic necessities and satisfy the greatest number of people with the line, form and general appearance of the structure.

Experienced designers tend to pay most attention to the point of maximum load or points of high loads and pay little attention to other parts of the structure. In general, this is a dangerous habit to fall into for the reason that a load applied to *any* part affects, in some degree, *every* part of a continuous structure. This is particularly true where the limiting factor in service is not resistance to fatigue, or strength, but total deformation under load. The behavior of the structure as a whole under load is what we are interested in and to form the habit of dealing only with areas of high loading may lead to serious error.

To summarize the course of our thought up to the present time (in this and the preceding articles):

In applying the welding processes, we must recognize the changes brought about in the original metal by applications of the welding heat cycle. These changes are frequently a subtraction of desirable properties, and due allowance must be made for what has been subtracted.

The ideal design meets economic necessities. Stated otherwise, the cost of use of the welded structure is less than the cost of use of some other kind of a structure.

The ideal design satisfies the artistic sense of the greatest number of people.

We must cut and form pieces of metal so that we can assemble, by welding, into a harmonious whole. Where complete freedom of action in forming the metal is inhibited by lack of equipment, the most harmonious combination must be chosen.